~~WHIM Backlight~~ Scaling relation fudge factor

~~Point source contaminant~~ Cooling problem ~~get-out clause~~

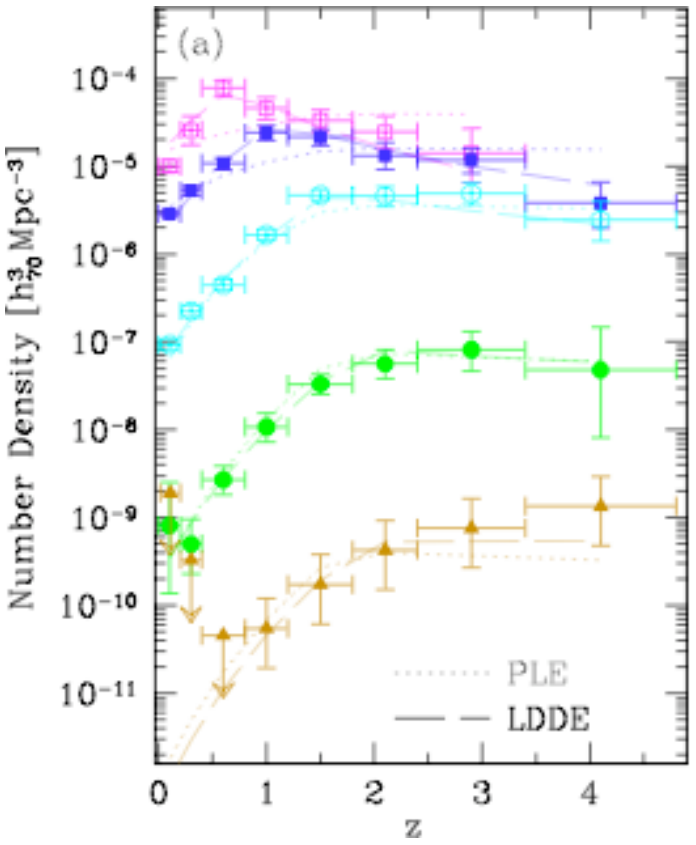
# ~~AGN~~/GALAXY COEVOLUTION

Kirpal Nandra
Imperial College London

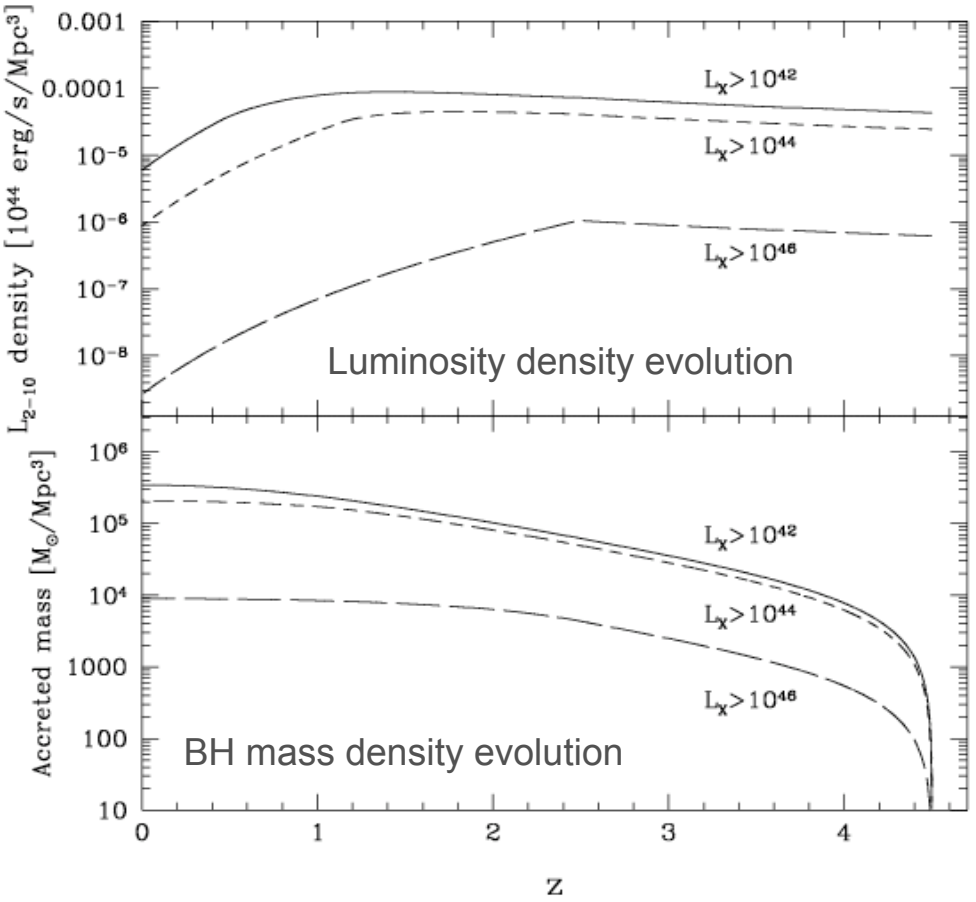

*With help from… Antonis Georgakakis, Elise Laird, Kevin Bundy, Alison Coil, Darren Croton and the AEGIS team….*

Imperial College London

# AGN EVOLVE




Hasinger et al. (2005)
Also Ueda et al. 2003

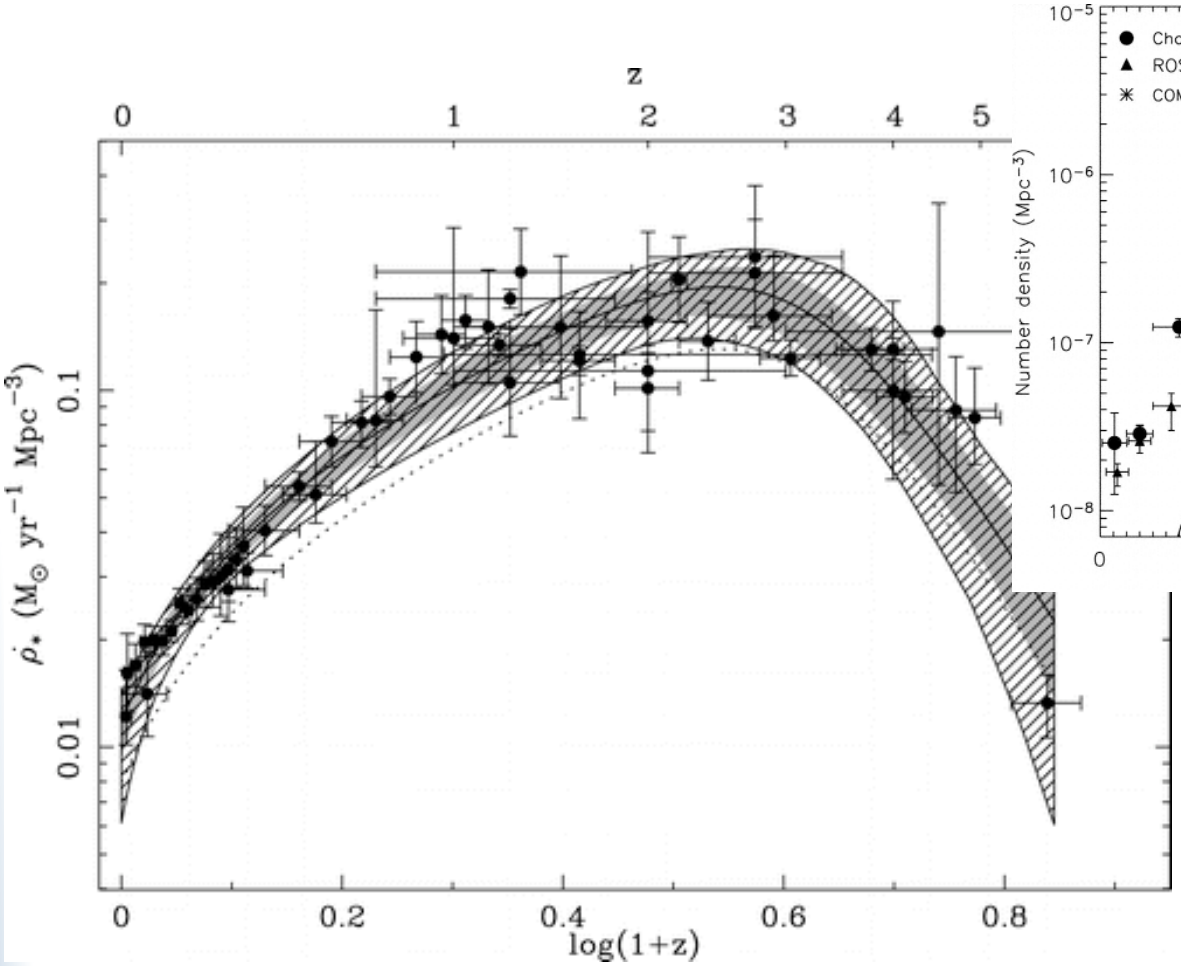



La Franca et al. 2005

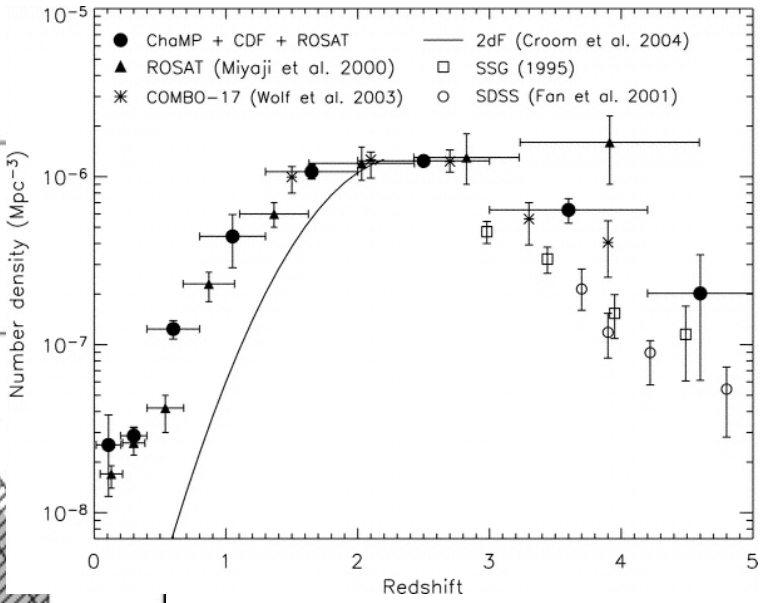
$\rho_{BH}$

Typical BH mass or accretion rate reduces with *z*?

# GALAXIES EVOLVE



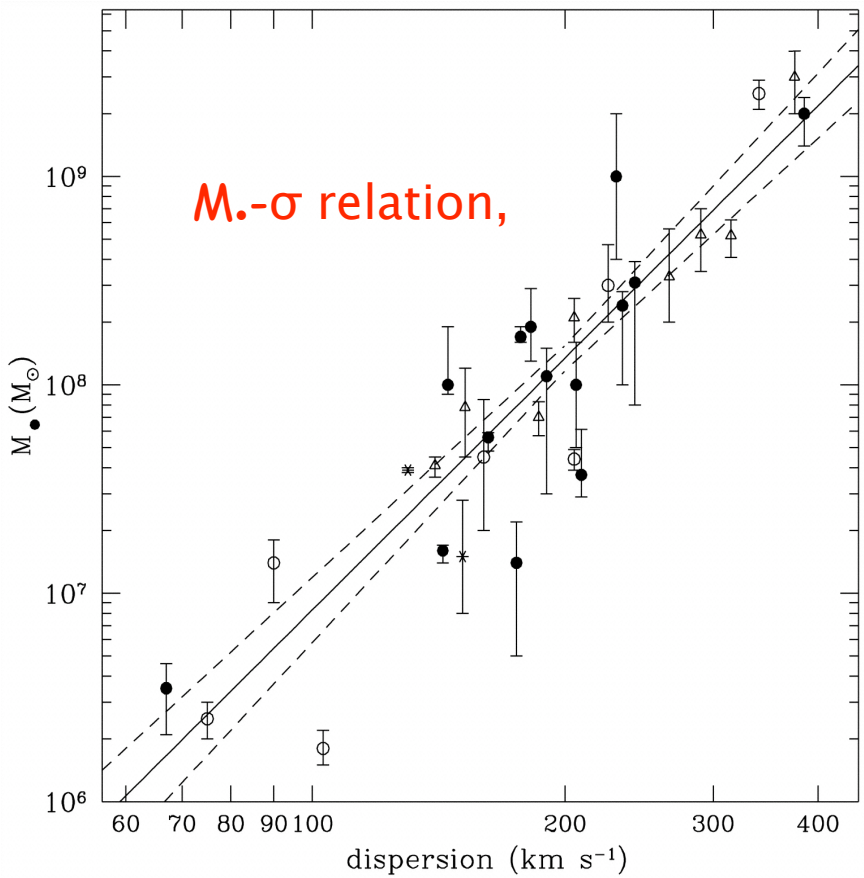

SFRD: Hopkins & Beacom (2006)




AGN number density:
Silverman et al. (2005)

Similar evolution:
Boyle & Terlevich 1998

# GALAXIES AND AGN CO-EVOLVE




- Black hole mass correlated to host galaxy bulge mass.
- Formation of bulge and growth of black hole are related.
- AGN play a significant role in the evolution of galaxies

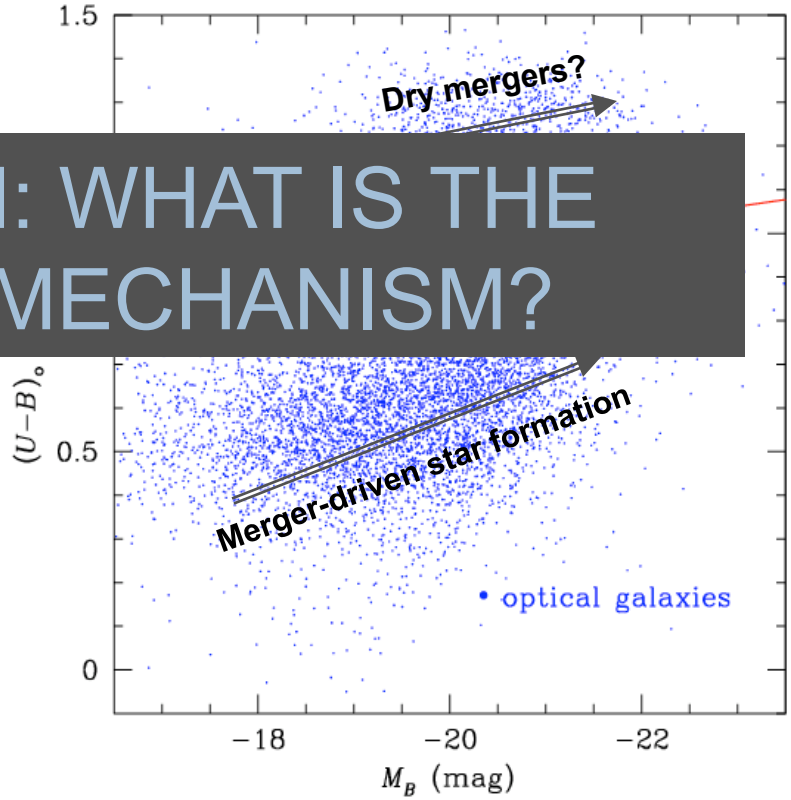
Magorrian et al. 1988; Gebhardt et al. 2000; Ferrarese & Merrit 2000; Tremaine et al. 2002

# GALAXIES EVOLVE (2)

- Colour bimodality:
  - Blue cloud: active star-forming
- 
- via mergers in blue cloud
- Rapid quenching to red sequence. Mechanism?
- Further red sequence growth via “dry mergers”?

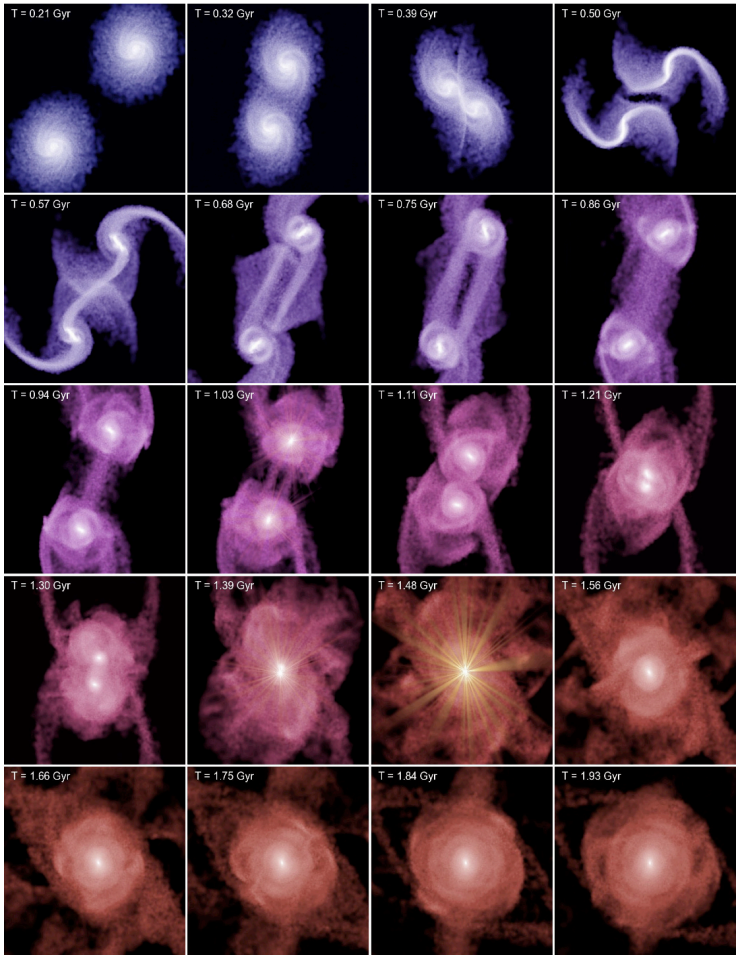
KEY QUESTION: WHAT IS THE QUENCHING MECHANISM?

DEEP2 survey, 0.4<z<1.4; Willmer et al. 2006



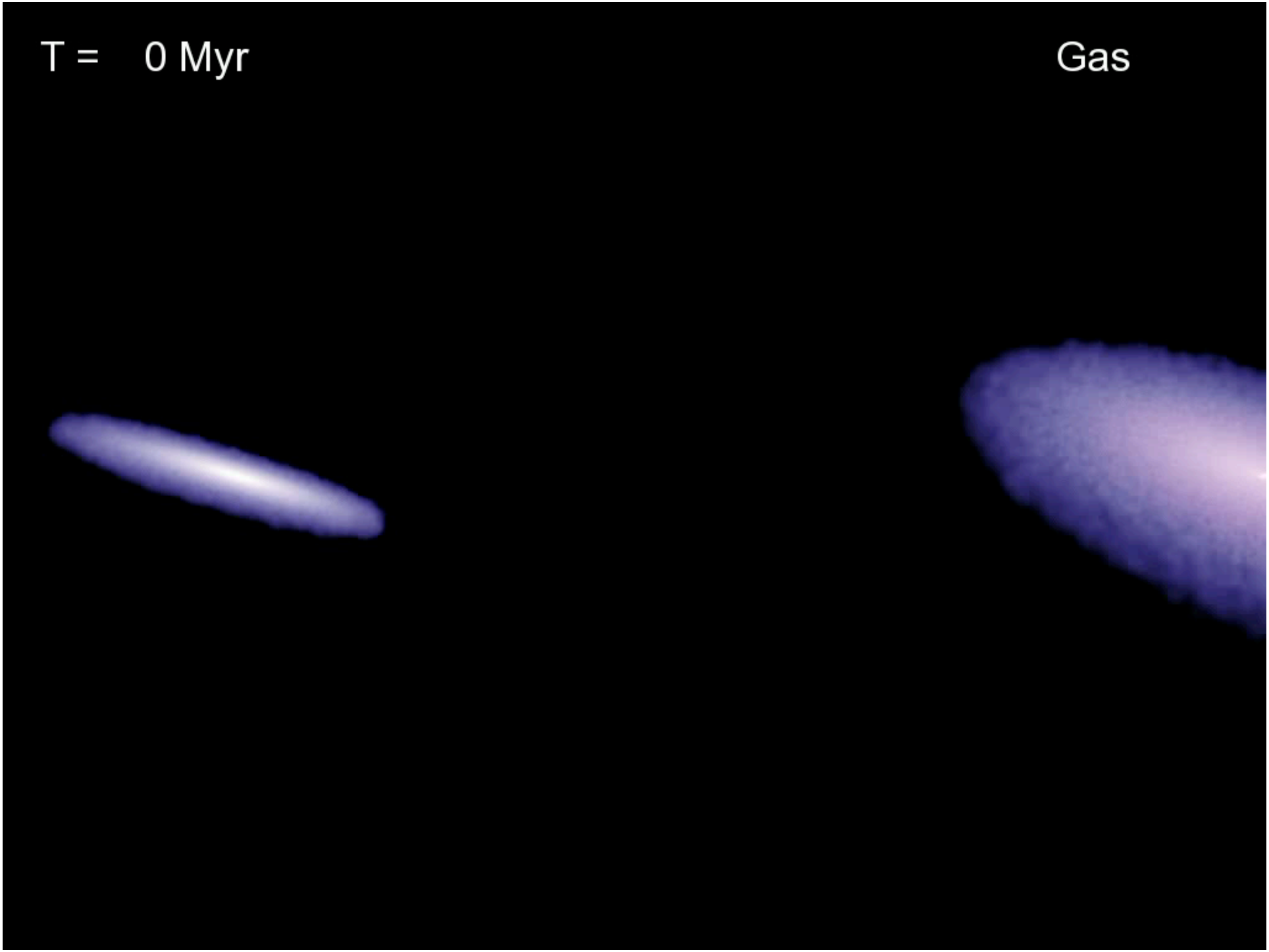

**e.g. Strateva et al 2001; Bell et al 2004; Faber et al 2008**

# QSO MODE FEEDBACK




- Gas rich major merger
- Inflows trigger BH accretion & starbursts
- Dust/gas clouds obscure AGN
- AGN wind sweeps away gas, quenching SF and BH accretion.

Hernquist (1989)
Springel et al. (2005)
Hopkins et al. (2006)


T = 0 Myr
Gas

# FEEDBACK AND THE M-σ RELATION

Winds drive out gas from galaxy when:

$$M_{BH} = \left(\frac{\alpha\kappa}{G^2 c}\right)\sigma^5$$ Silk & Rees (1988)

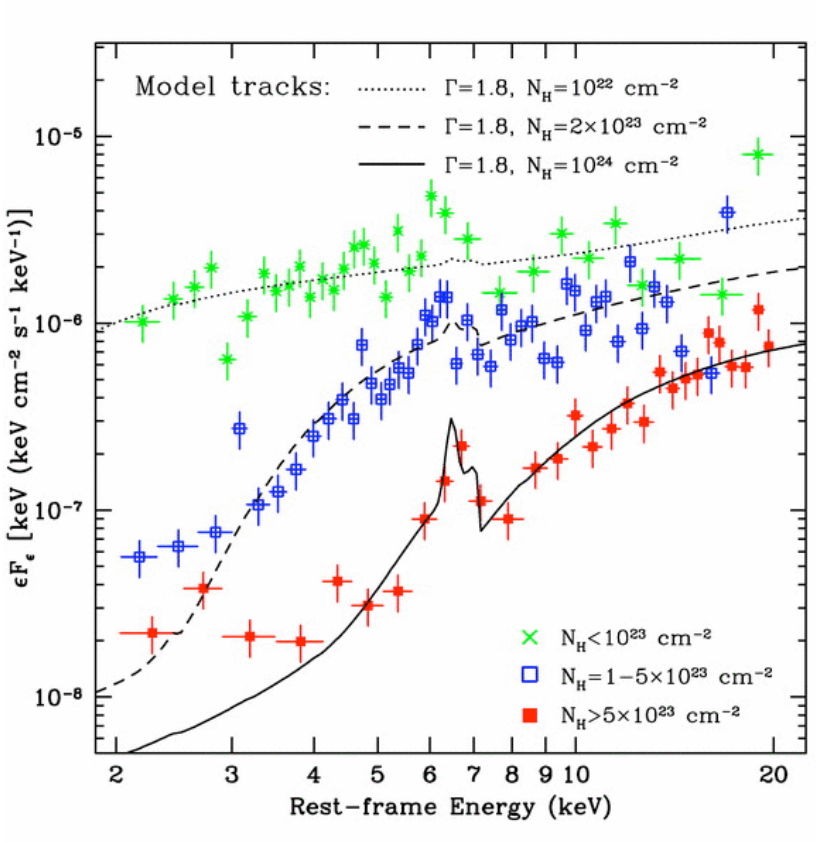
$$M_{BH} = \left(\frac{f_g\kappa}{2\pi G^2}\right)\sigma^4$$ King 2003

$$M_{BH} \propto \sigma^{\beta} \qquad \beta = 4.0 \pm 0.3$$

Tremaine et al. 2002

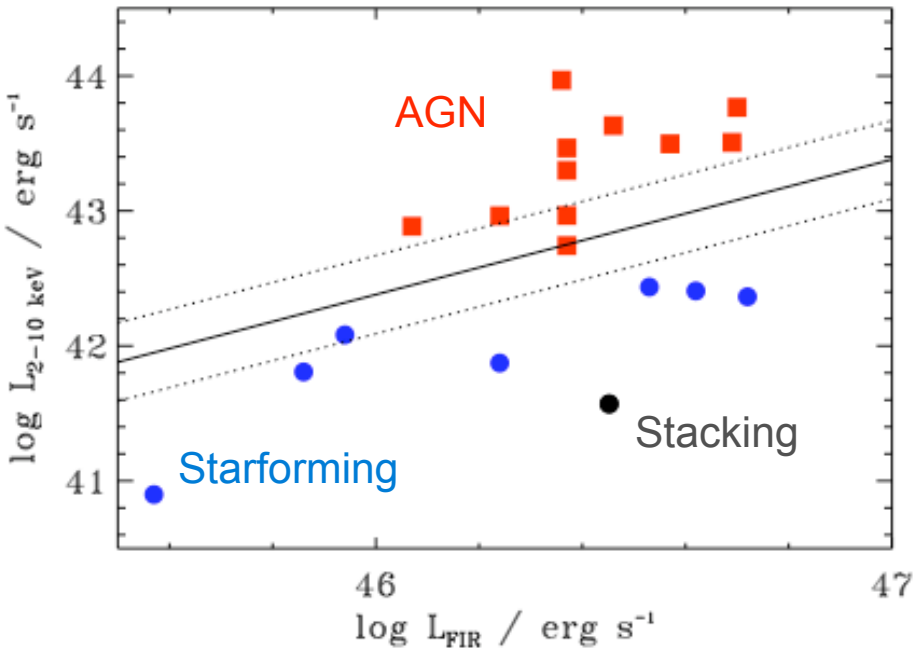
# CO-EVAL STAR FORMATION/BH GROWTH?

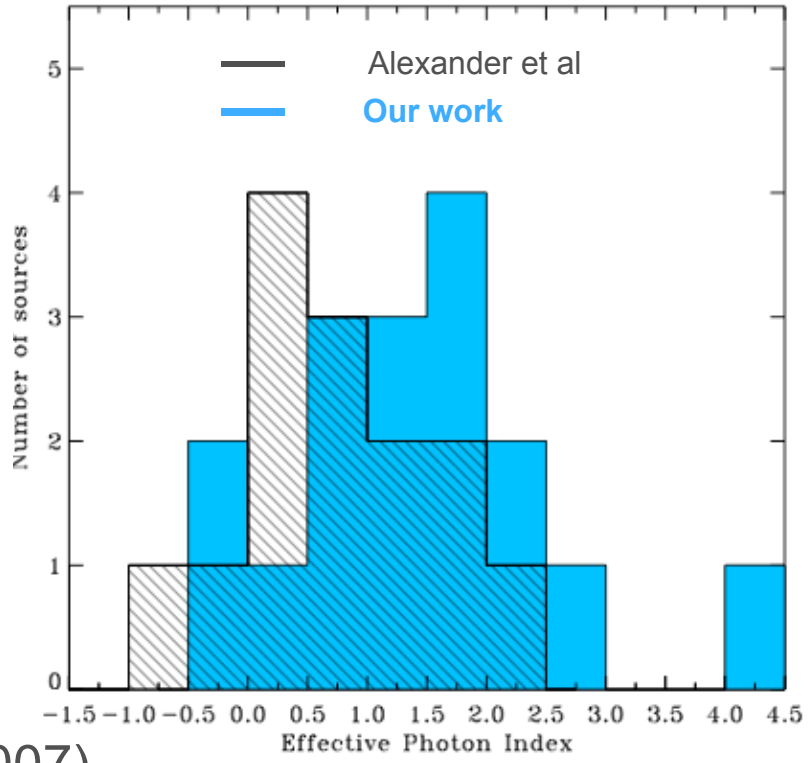
- Submm emitting galaxies undergoing intense SF
- Many detected in X-rays
- >40% (100%?) of radio bright sources w/submm emission are AGN
- “Continuous” BH growth
- Hard X-ray spectra
- ***Co-eval obscured SF and accretion: QSO mode?***




**Chapman et al. 2003; Alexander et al. 2005a,b**

# CO-EVAL STAR FORMATION/BH GROWTH?



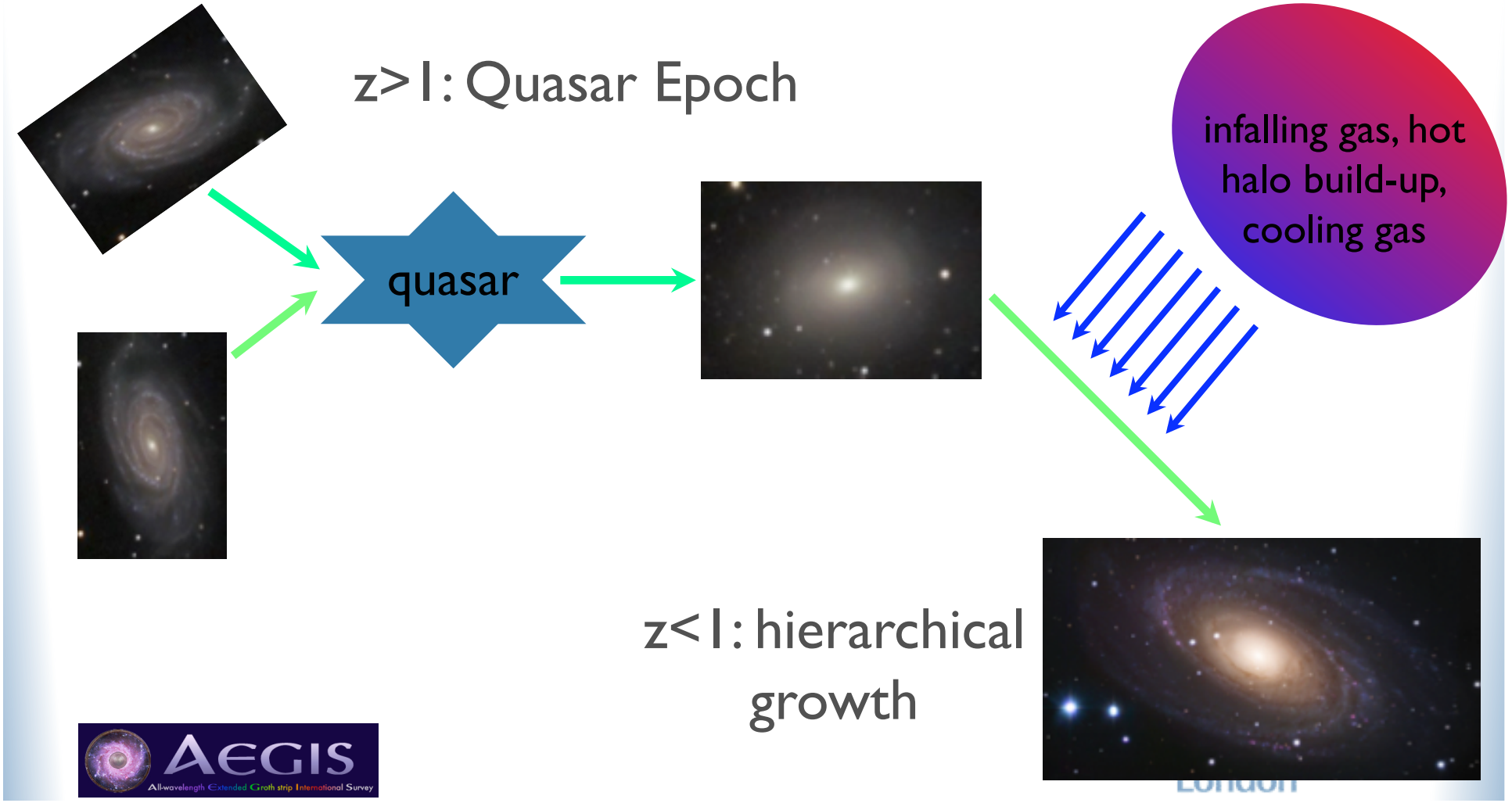

Pure submm sample of Pope et al. (2007)

~25% AGN, spectra not particularly hard

**Laird et al. (2008)**

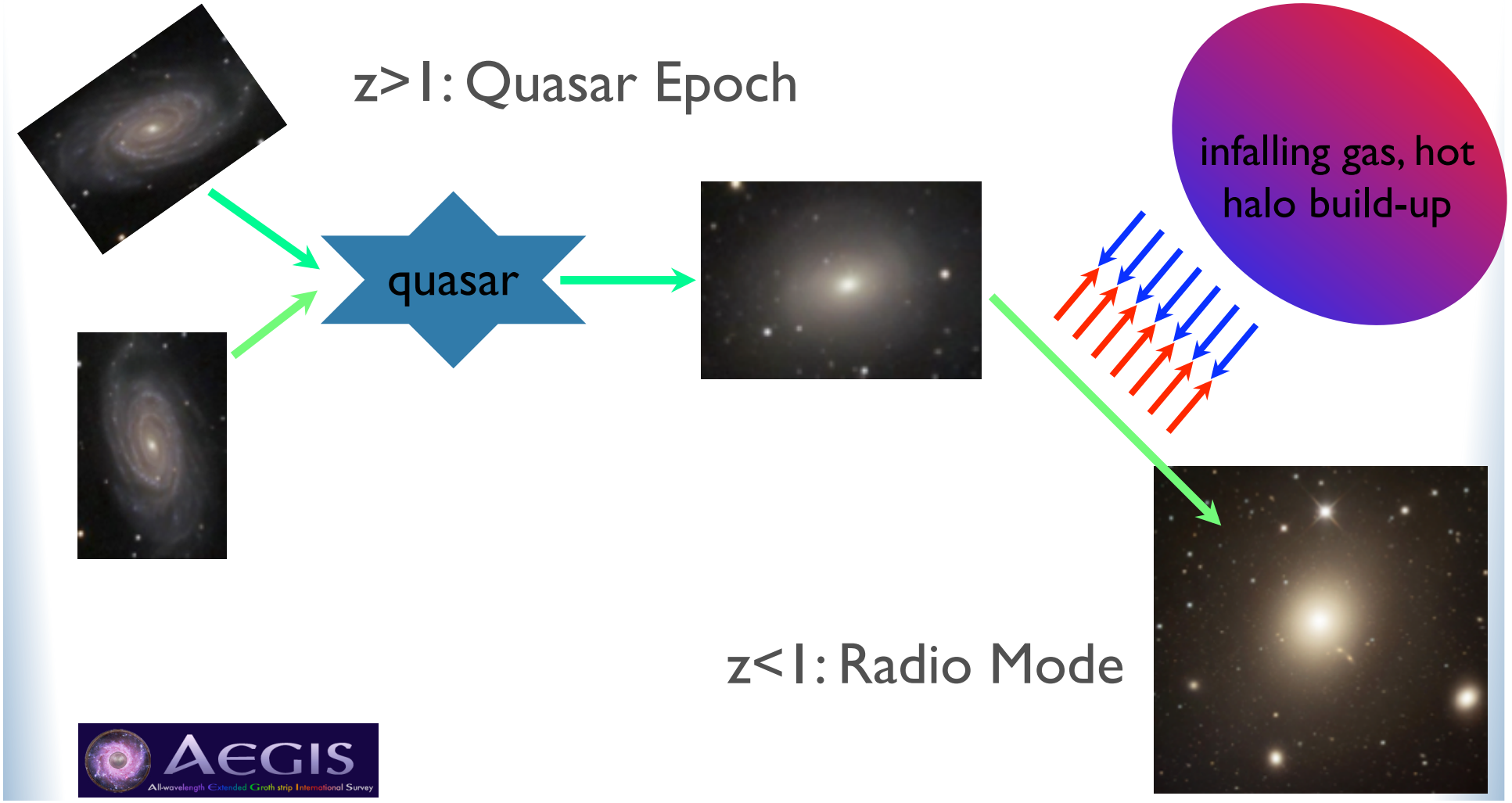
# RADIO MODE FEEDBACK

Croton et al. 2006



# RADIO MODE FEEDBACK

Croton et al. 2006




AEGIS
All-wavelength Extended Groth strip International Survey

# AGN FEEDBACK

| | When? | Trigger? | Feeding? | Consequence? |
|---|---|---|---|---|
| Quasar Mode | at early times | gas rich mergers | cold gas | BH growth, sets properties of ellipticals |
| Radio Mode | at late times | BH & hot halo large enough? | hot gas? stellar winds? | suppresses cooling gas, shuts down SF |

A complete picture of galaxy evolution probably needs both

AEGIS All-wavelength Extended Groth strip International Survey

Imperial College London

# THE AEGIS SURVEY

- ***AEGIS-X***
- ***Chandra* AO-3:**

200ks over 0.08 deg$^2$
**(Nandra et al. 2005)**

- *Chandra* AO6:

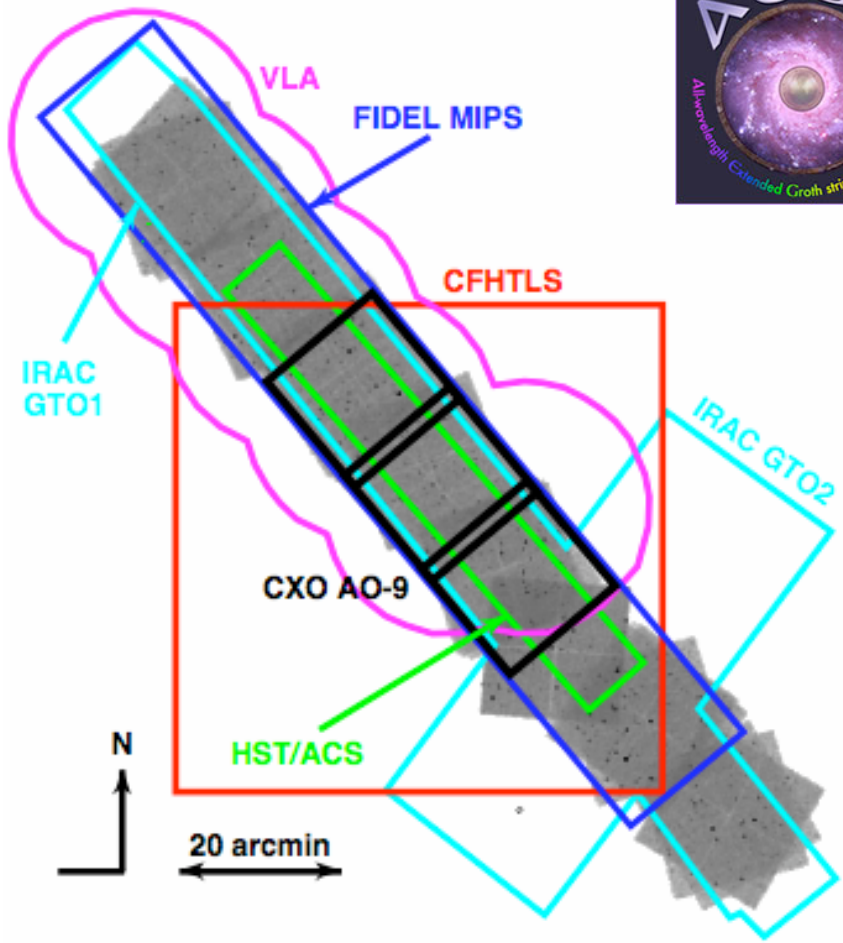
**1.4 Ms over 0.5 deg$^2$**

*80 (70)% of soft (hard) XRB*
**(Laird et al. 2008)**

- *Chandra* AO-9:

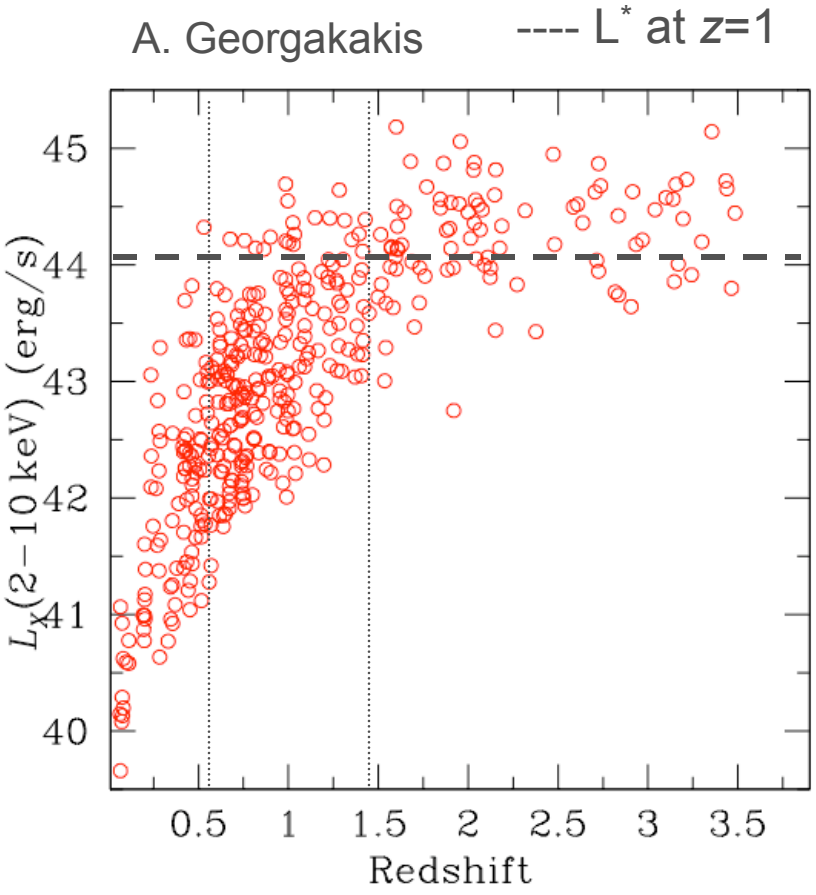
**1.8 Ms over 0.2 deg$^2$**

- DEEP 2/3 spectroscopy, FIDEL MIPS, HST, IRAC GTO, VLA, GALEX, CFHTLS blah blah blah




aegis.ucolick.org; Davis et al. (2007)

# THE AEGIS-X SURVEY




X-ray: Laird et al. 2008

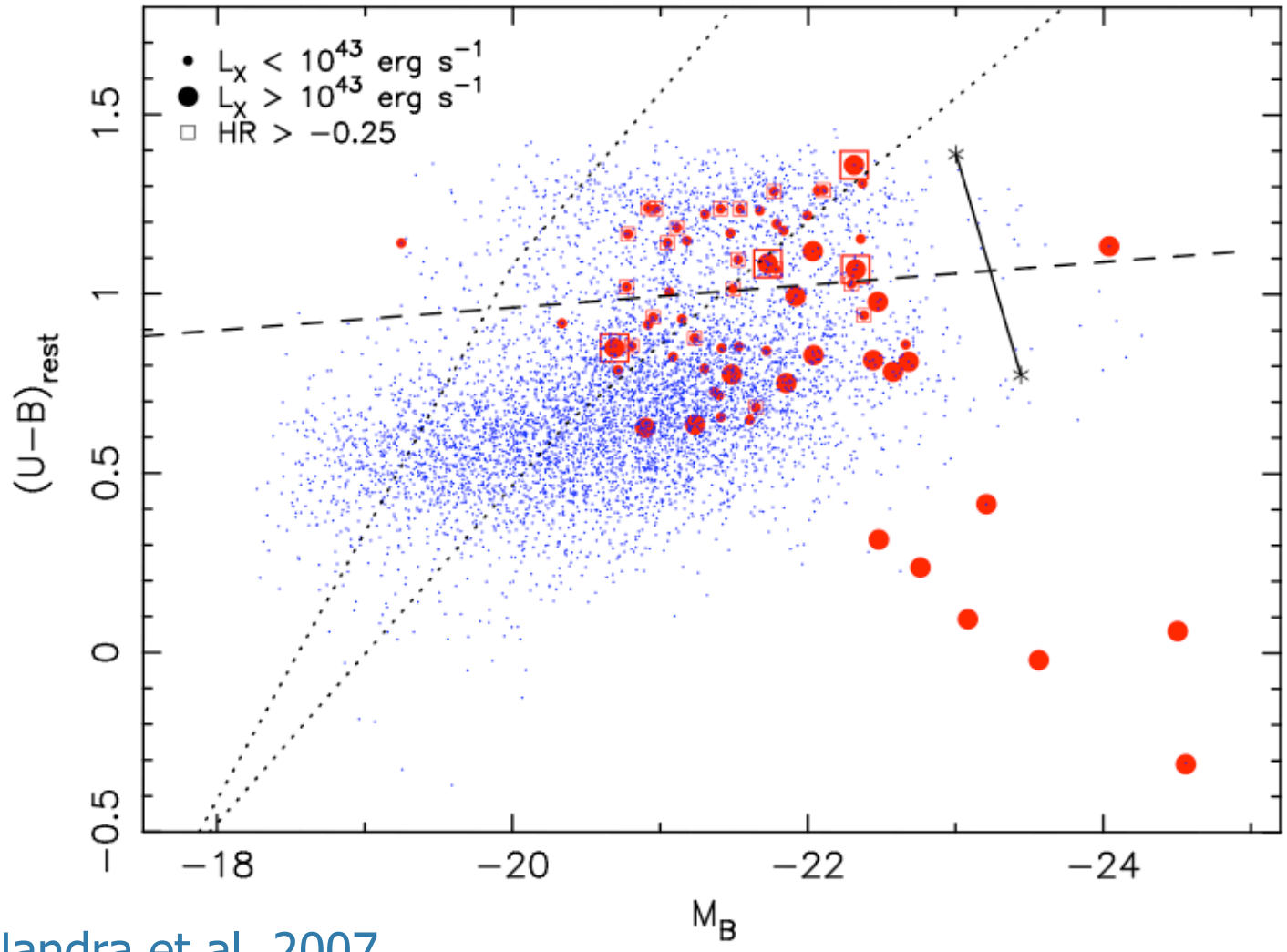
- 1325 X-ray sources
- ~35% spectroscopic completeness
- (DEEP3 ⇒ 60%)
- Photometry, BRIK
- (CFHTLS/IRAC, good photoz)

Spectroscopy:
- Keck/DEEP2 (Davis et al. 2003)
- MMT Coil et al. (2008)

# RELEVANT OBSERVATIONS

- AGN host galaxy colours and star formation
- Morphologies
- Stellar Mass Function
- Large scale structure environment
- Relationship to groups

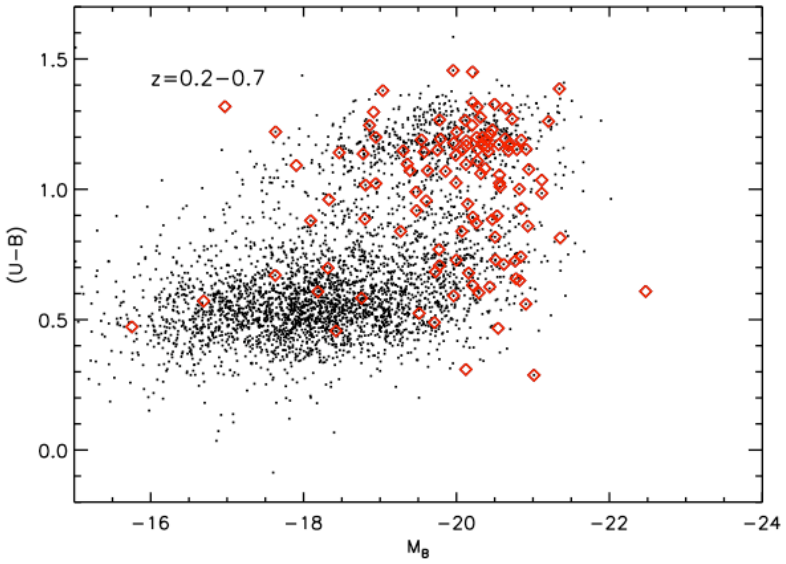
# THE AGN COLOR-MAGNITUDE RELATION



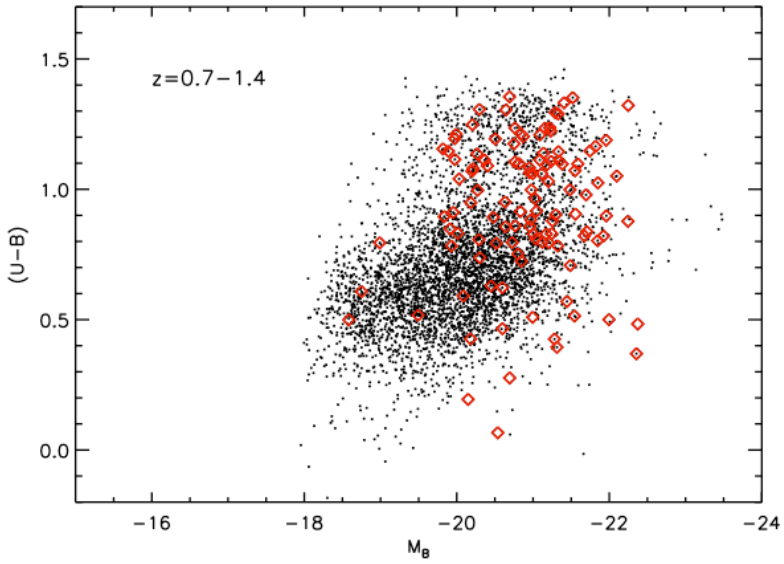

Nandra et al. 2007

# THE AGN COLOR-MAGNITUDE RELATION

z=0.2-0.7



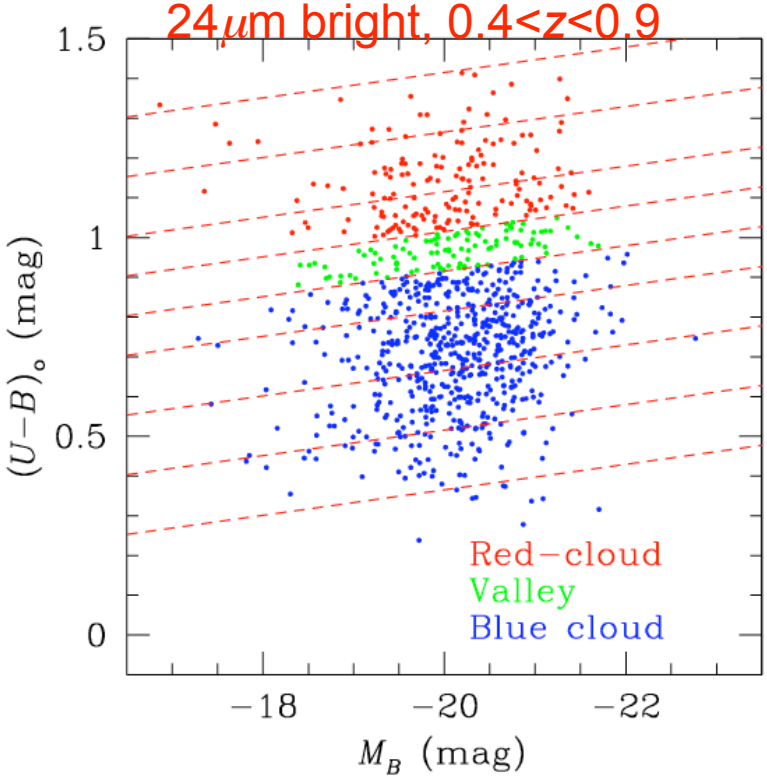

z=0.7-1.4

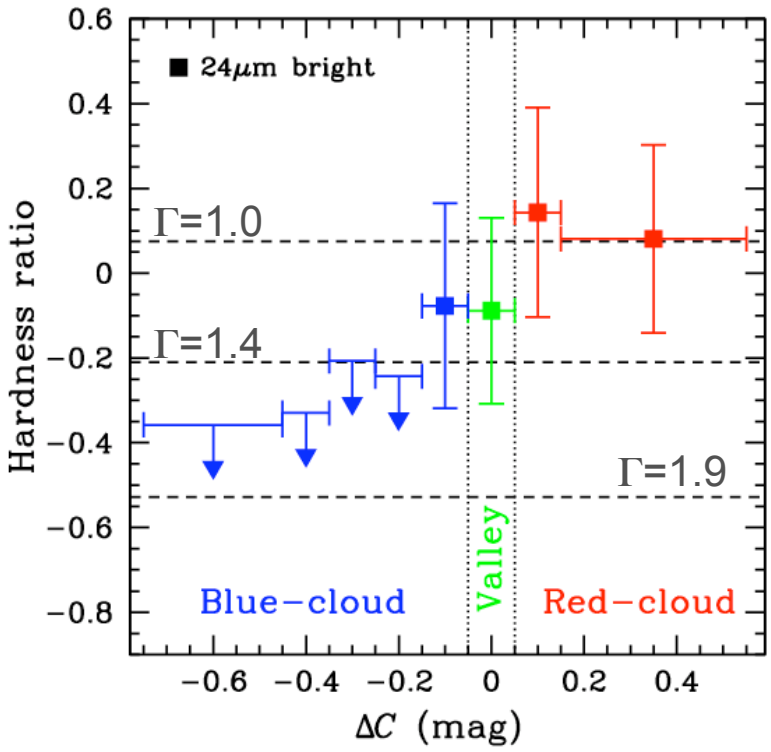



Coil et al. 2008

# X-RAY STACKING VERSUS COLOUR

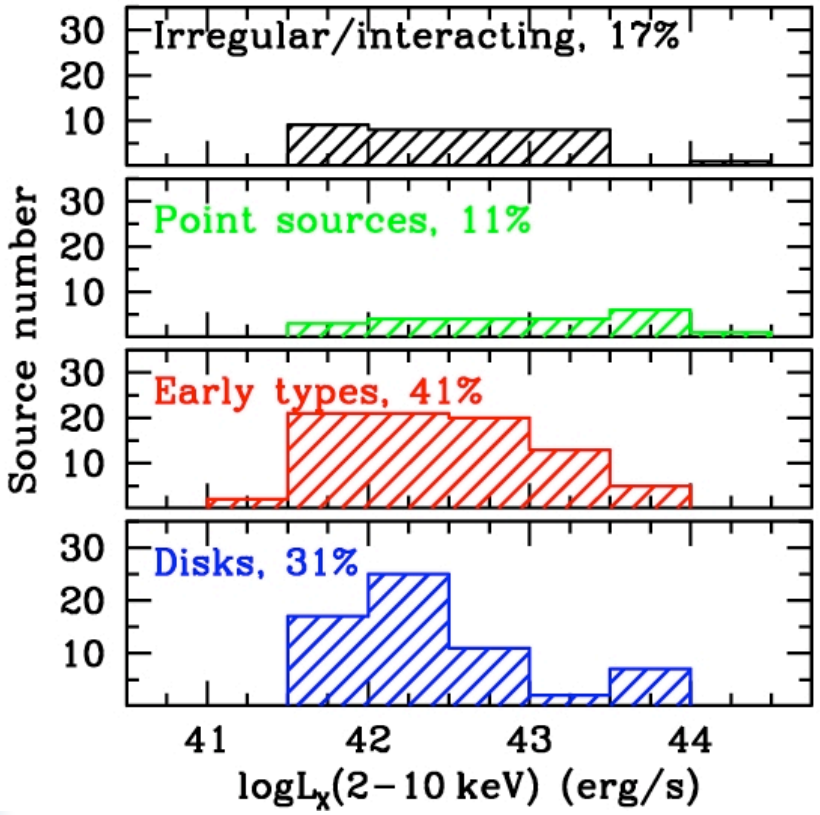
Georgakakis et al. (2008)

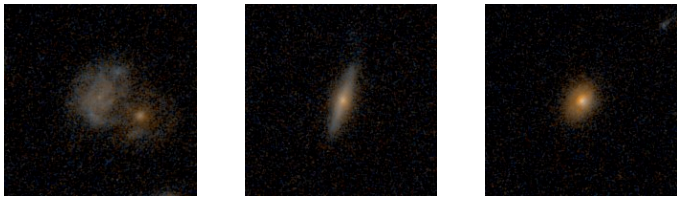



- Hard signal around valley and in red cloud, $\Delta C > -0.15$
- Obscured AGN associated with transition galaxies

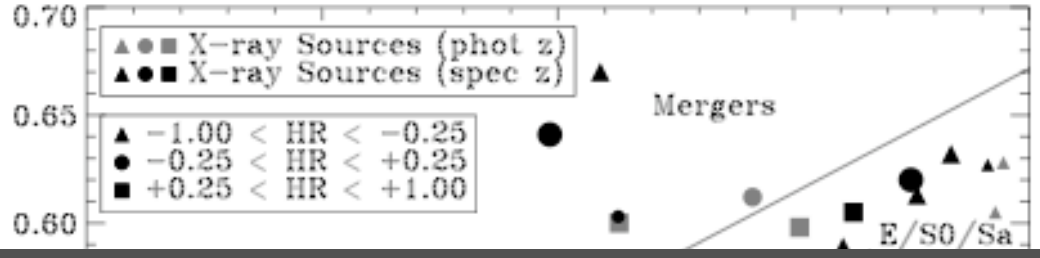
# AGN HOST MORPHOLOGIES



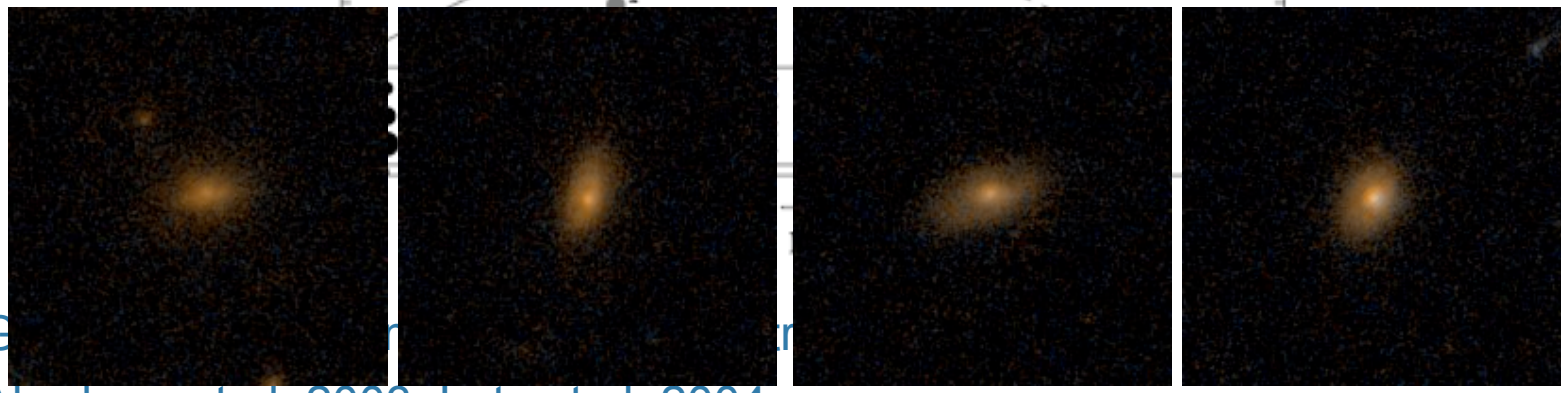



- CDFs+AEGIS 0.7<z<1.3
- Bulges dominate (merger remnants?)
- Spirals 2nd larger group
- Ongoing interactions minority

# HOST GALAXY MORPHOLOGIES




MASSIVE, BULGE DOMINATED, RED, EVOLVED HOSTS



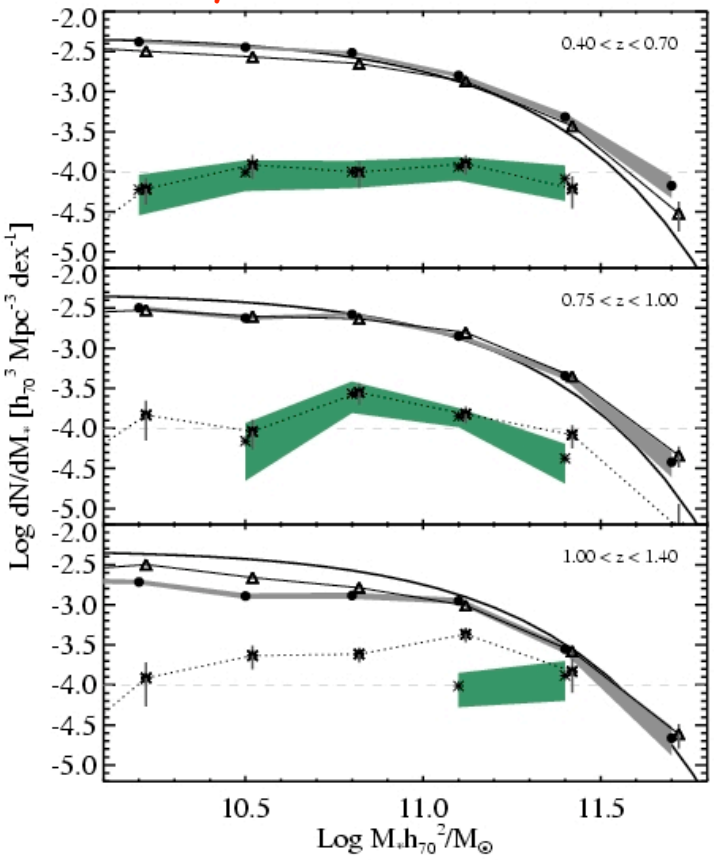
G r

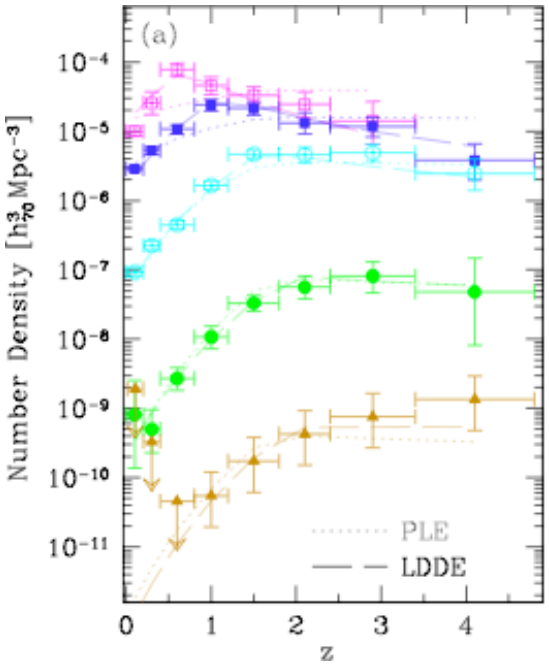
Abraham et al. 2003; Lotz et al. 2004

Pierce et al. 2007

# AGN STELLAR MASS FUNCTION

Bundy et al. 2008



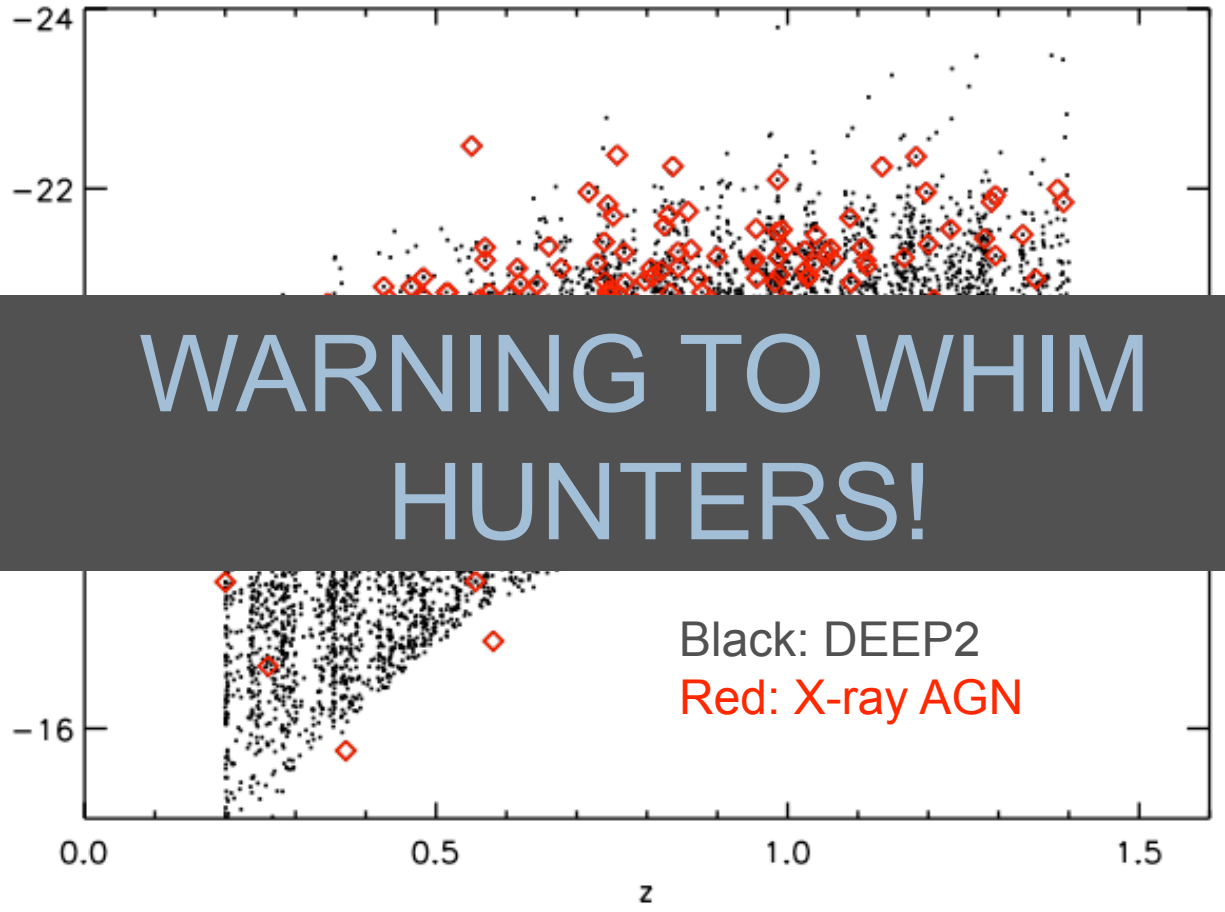

No Evidence for AGN Hosts "Downsizing" in mass

**⇒Accretion rate evolution?**

Also Babic et al. 2007

# LARGE SCALE STRUCTURE ENVIRONMENT

A. Coil



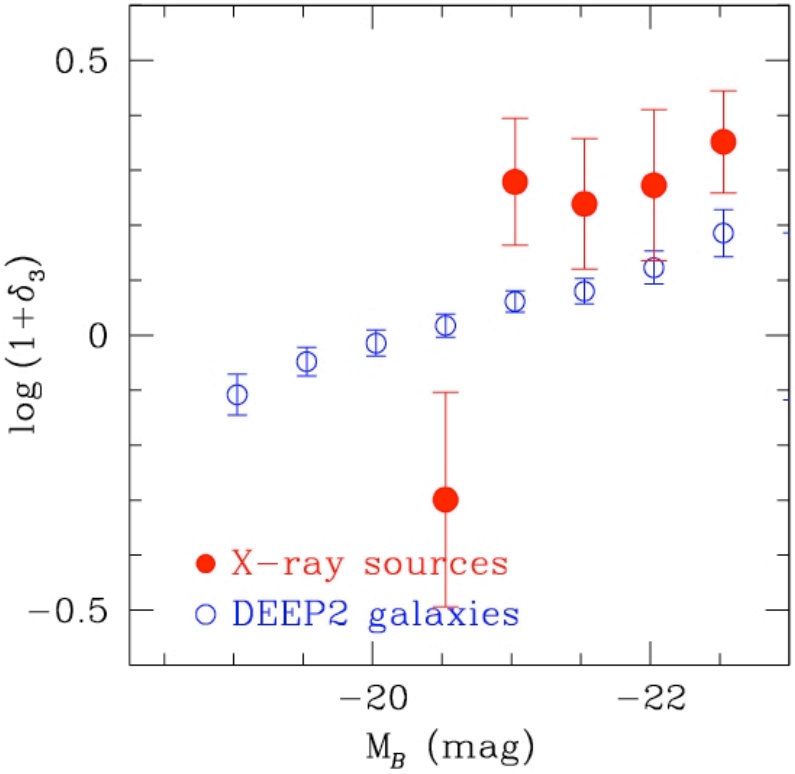

WARNING TO WHIM HUNTERS!

AGN: Massive galaxies tracing large scale structure

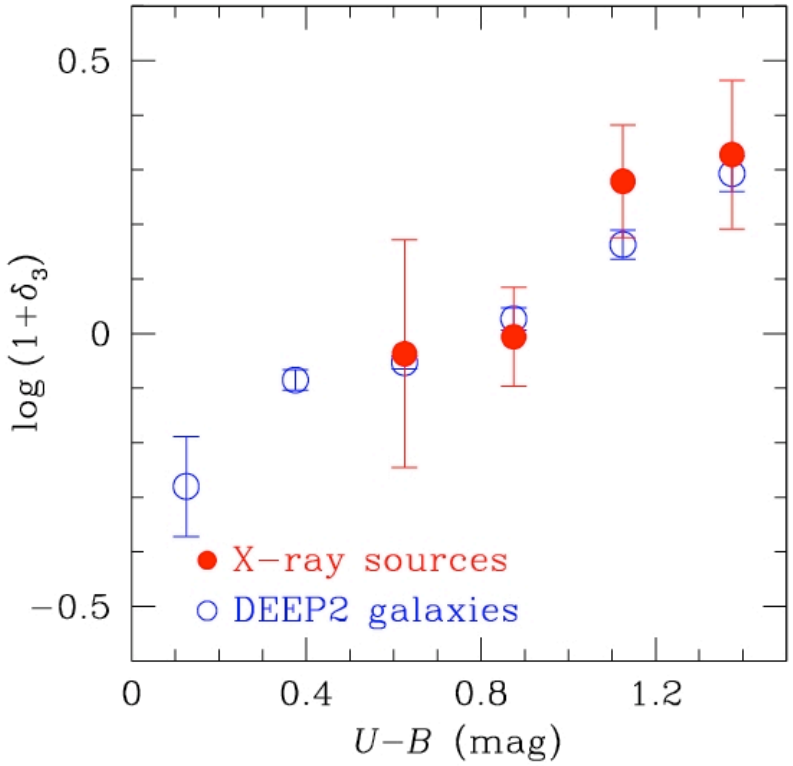
Also ECDF-S: Silverman et al. 2008; Xbootes Murray et al. 2005; Hickox et al. 2008

# LARGE SCALE STRUCTURE ENVIRONMENT

vs. host luminosity




vs. host colour

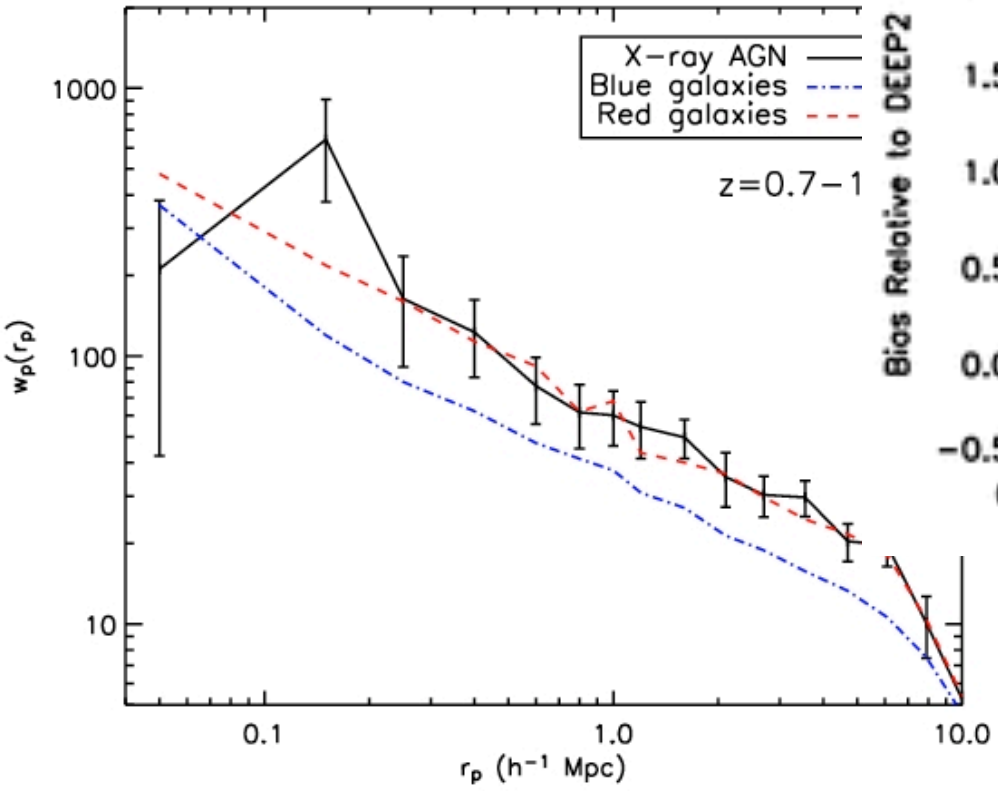


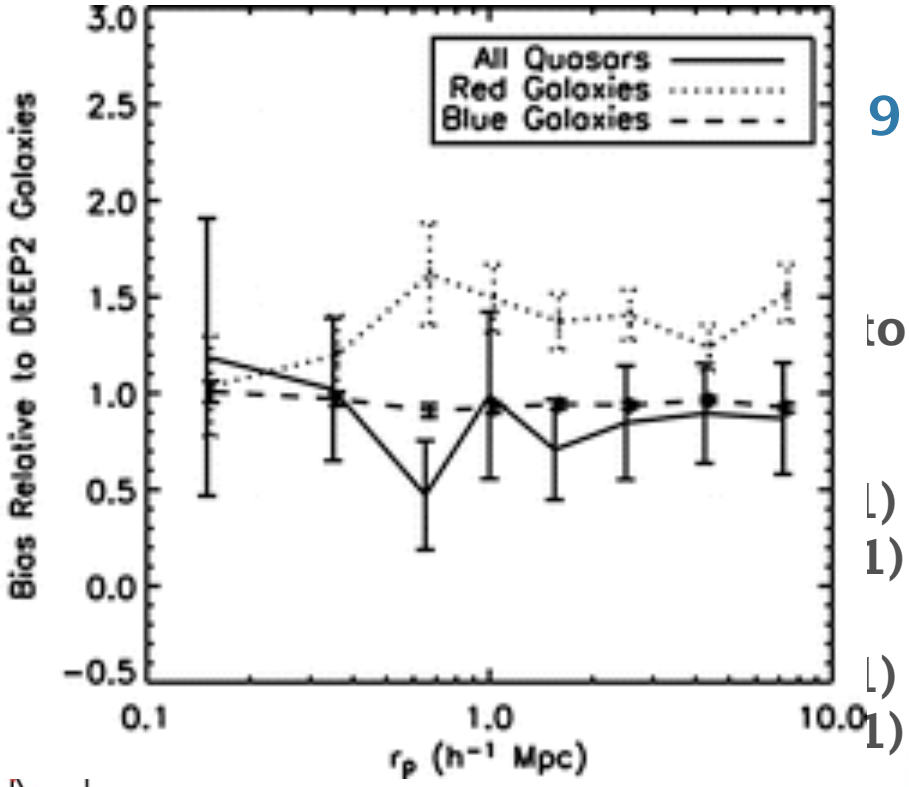

**Georgakakis et al. (2007)**

**Comparing with galaxies samples same range of LSS**

# AGN/GALAXY CROSS-CORRELATION

Split into 2 redshift bins:
X-ray AGN cluster like red gala




9

to

L)
1)

L)
1)

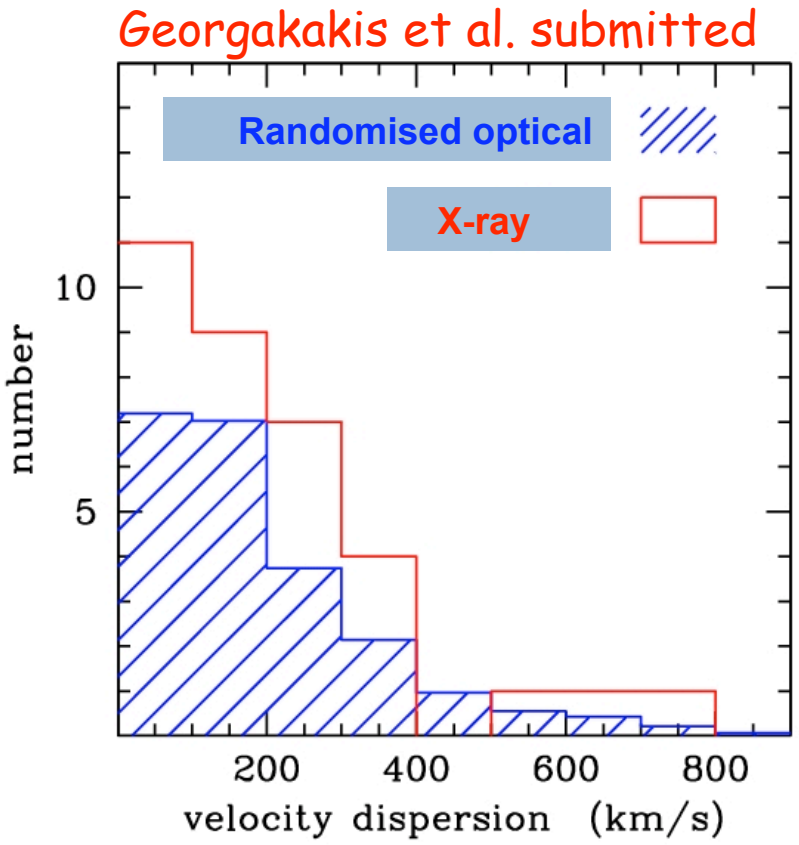
Coil et al. 2008

Coil et al. 2006

# AGN: RELATIONSHIP TO GROUPS

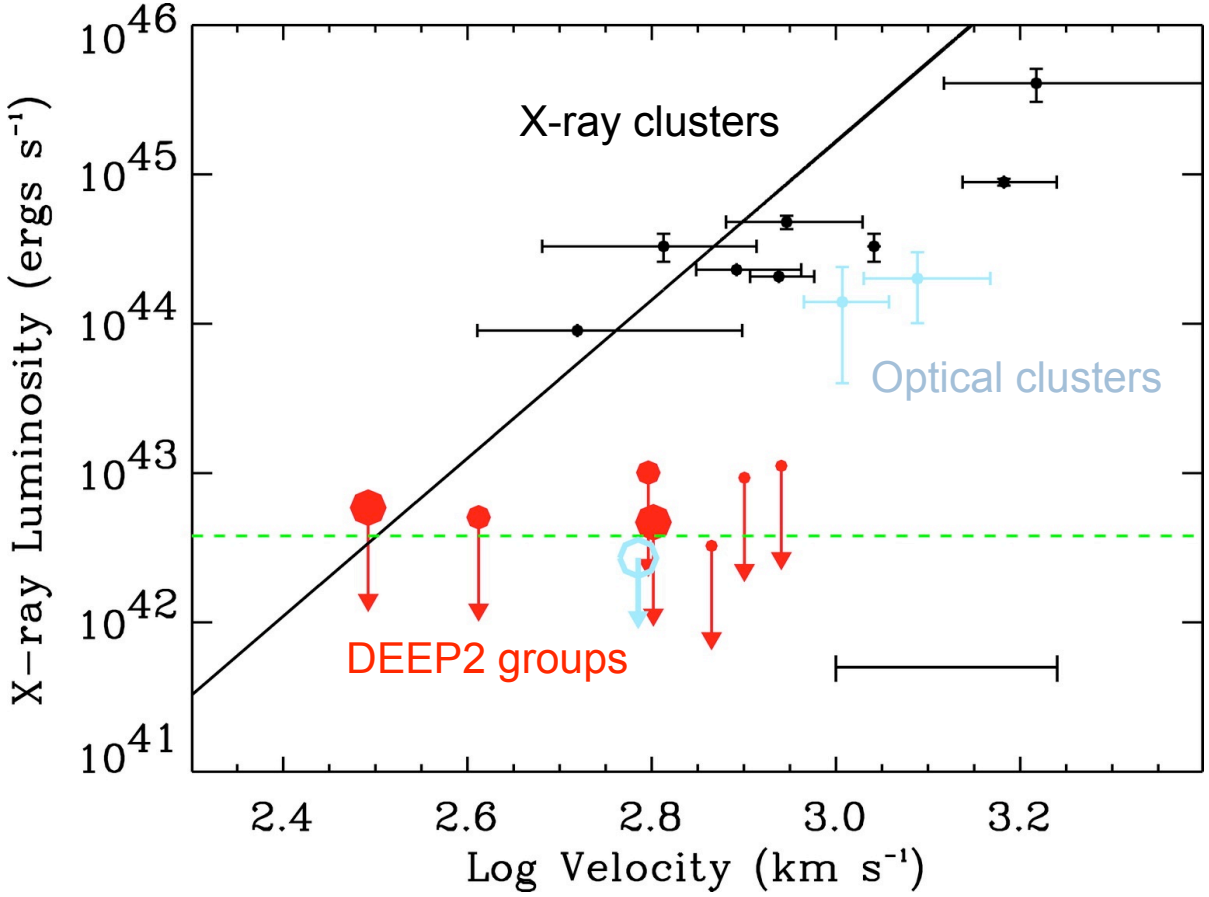
- Gerke et al. (2006) optical spectroscopic groups
- **40% of X-ray AGN in groups**
- Excess compared to general population (~99%)
- Tentative excess relative to matched galaxy population (~90%)

See also: Miyaji et al. 2007; Silverman et al. 2008



# NON-DETECTION OF DEEP2 GROUPS

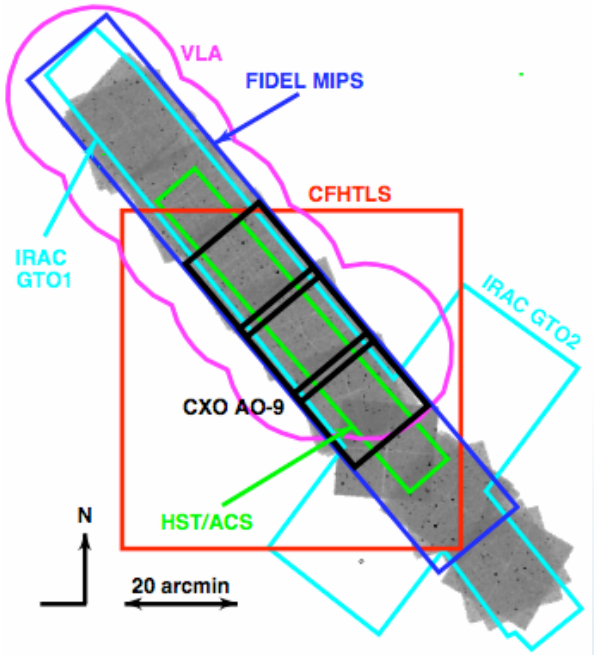
Spectroscopically selected groups at z>0.7 (Gerke et al. 2006)



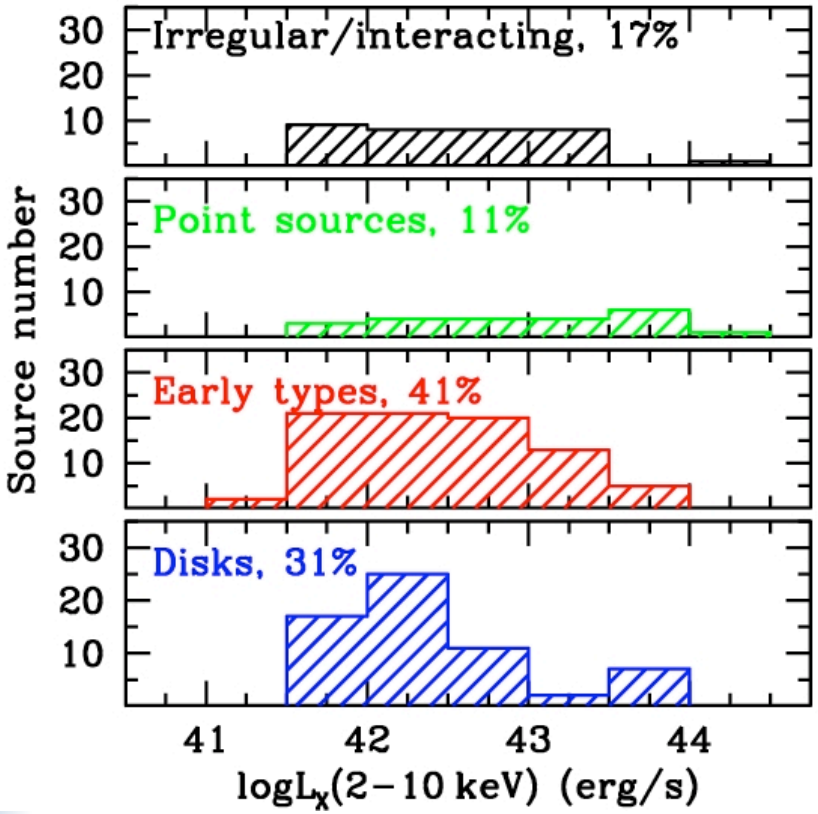

**Fang et al. (2007)**

# CONCLUSIONS

- Typical AGN at *z*~1 are in massive, red host galaxies
  - Star formation has terminated or is terminating
  - Many obscured AGN on red sequence
  - Bulge dominated, ~0 mergers
- Stellar Mass Function
  - Flat, non-evolving, no downsizing in mass
- Large scale structure environment
  - Dense environments (cluster like hosts)
  - Around ~50% in groups
- ***Most BH growth not in "QSO mode"***
- No high z group extended X-rays (yet)
- More to come!



# Morphology of AGN hosts at z~1




- CDFs+AEGIS 0.7<z<1.3
- Bulges dominate (merger remnants?)
- Spirals 2nd larger group
- Ongoing interactions minority



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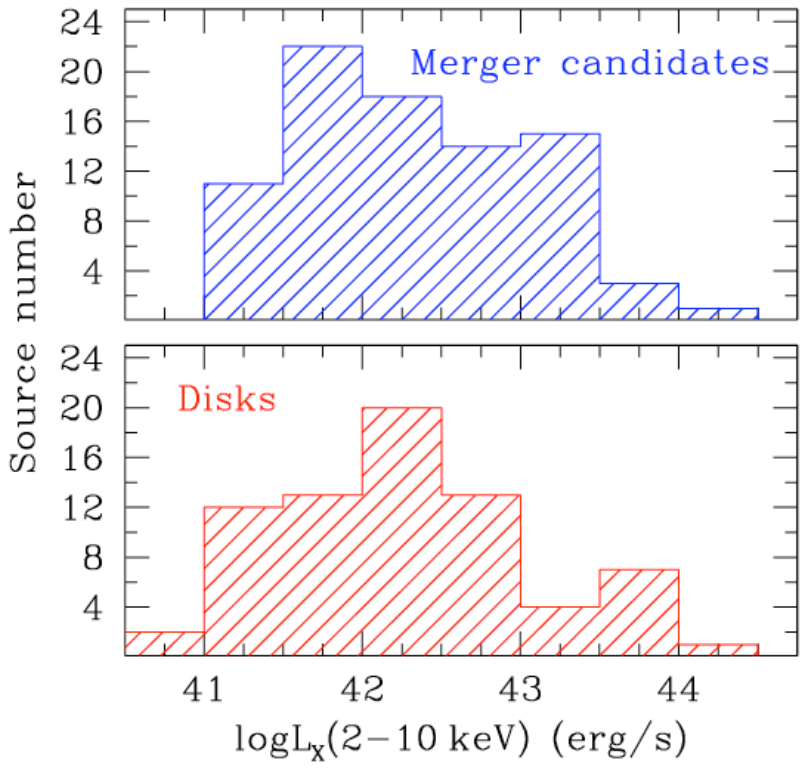
# AGN host galaxy morphology: mergers or merger remnants?



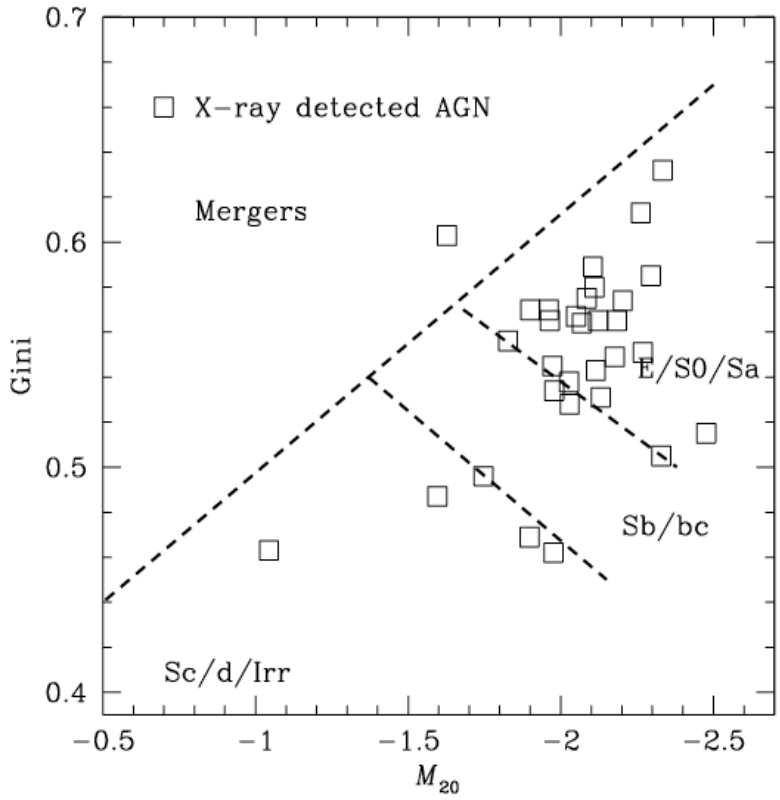

- AEGIS and CDF-North
- Morphological classification (HST):
  - mergers (ellipticals, interacting, QSOs)
  - Disks (spirals)

Only 50% of AGN in major-mergers

# X-ray source optical morphology

## Gini–$M_{20}$ diagram (Lotz et al. 2004):

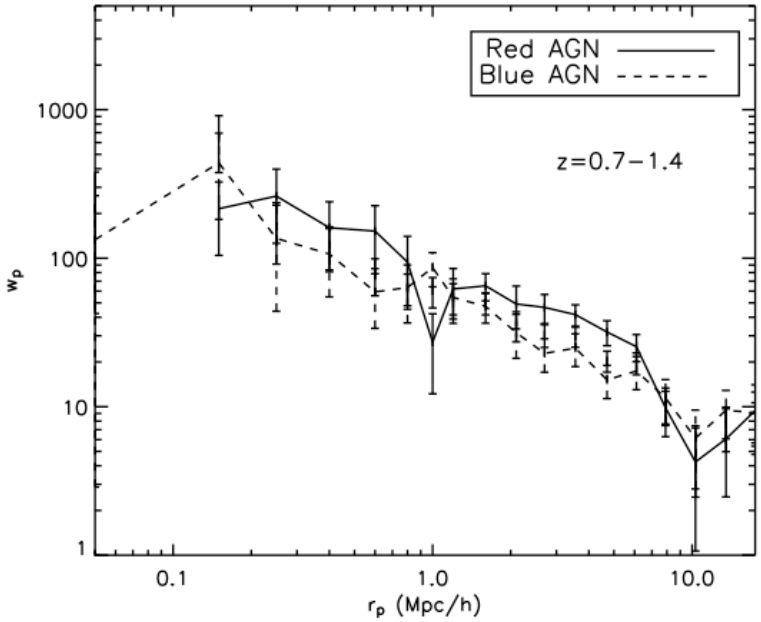
- Gini: distribution of galaxy's flux
- $M_{20}$: 2nd moment of the brightest 20% of the galaxy's flux



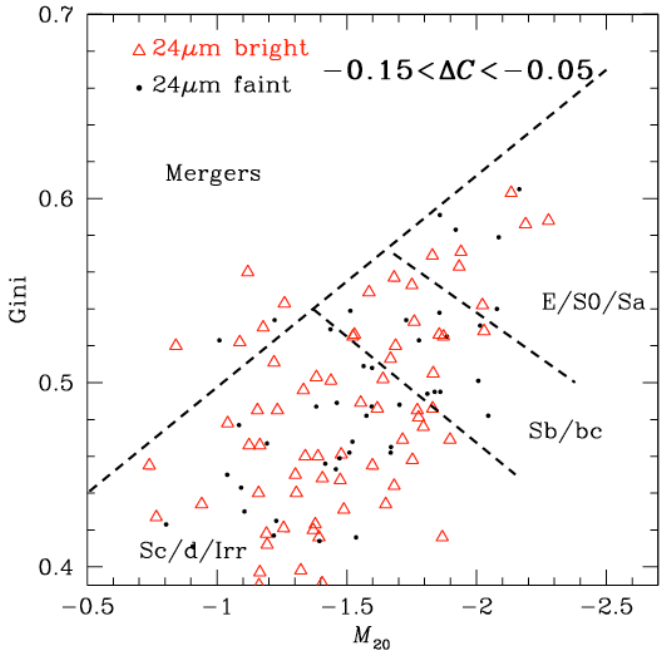

X-ray AGN: bulge dominated

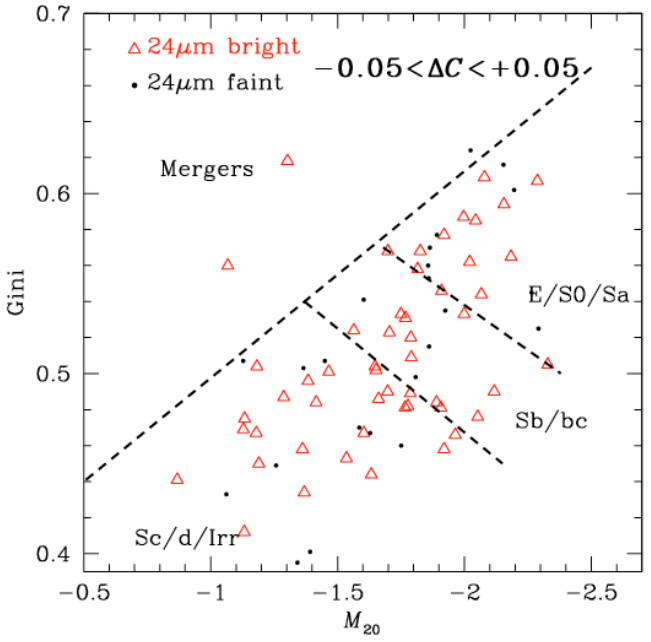
# COLOUR-DEPENDENCE

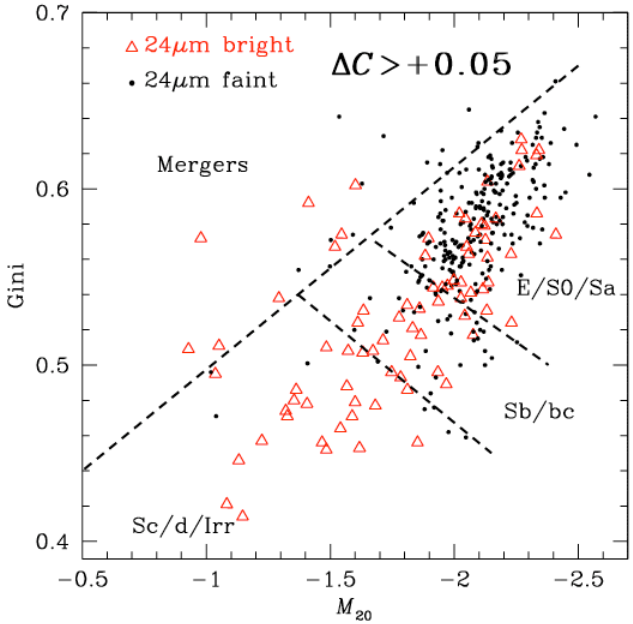
AGN on red sequence are more clustered than in blue cloud

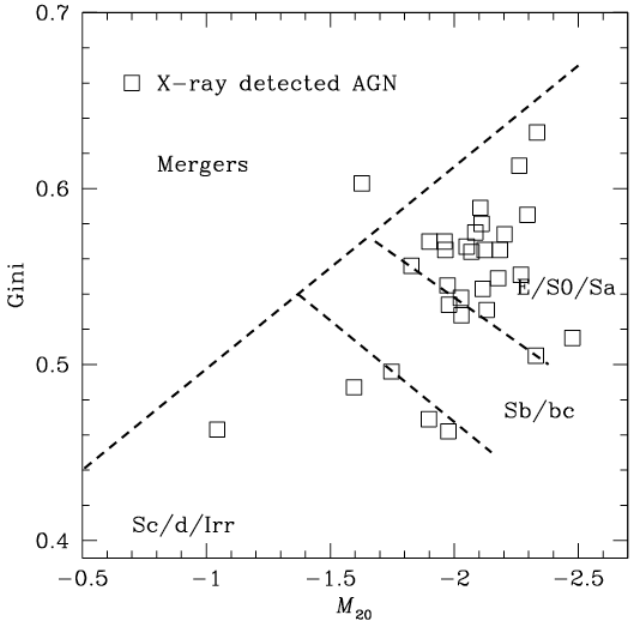


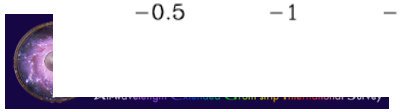

**Coil et al. in prep**



ra: AGN/Galaxy (
mbia Warm/Hot I

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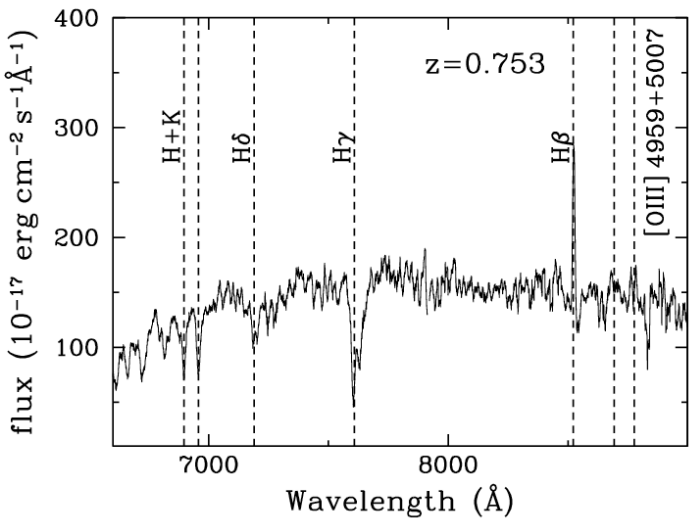
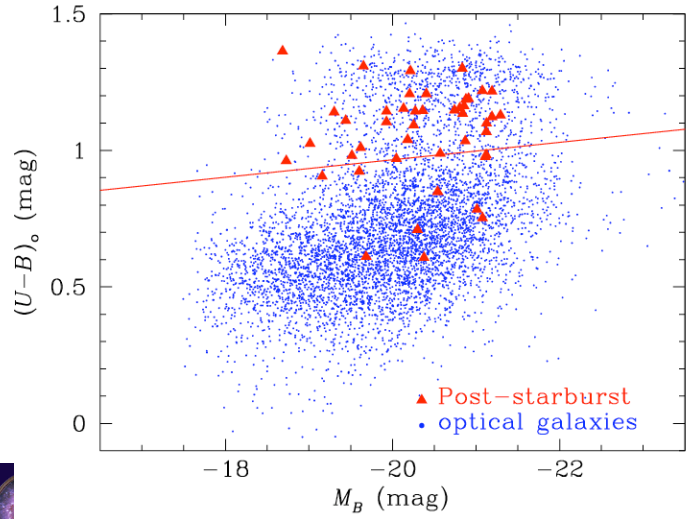
# AGN in post-starbursts at z~1



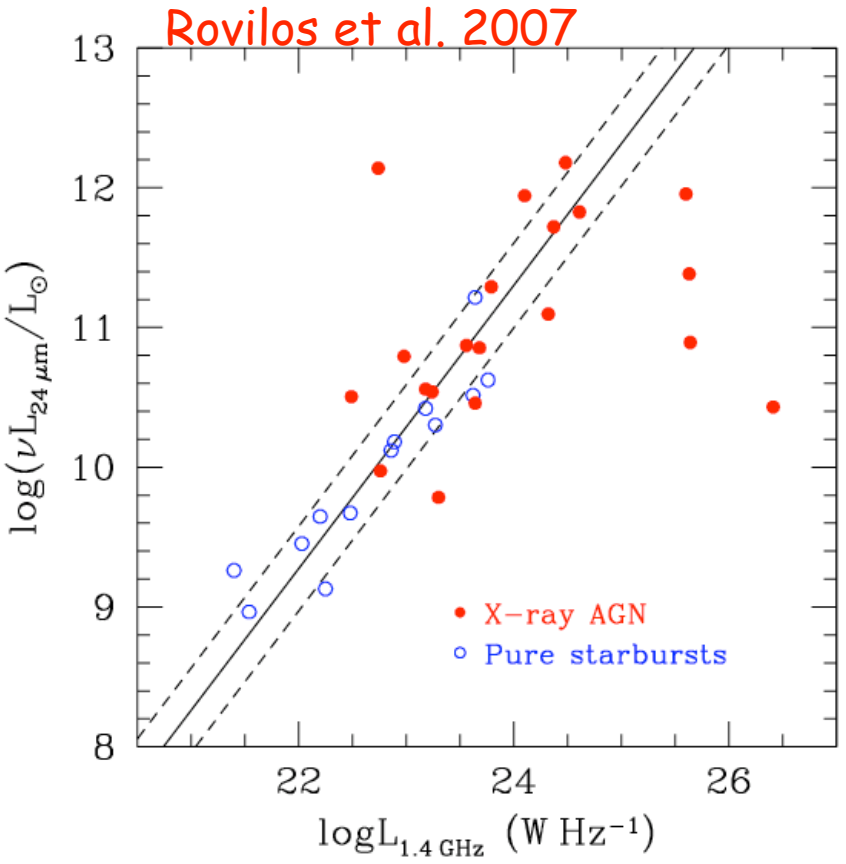




44 AEGIS galaxies with post-starburst spectra (0.7<z<0.9)

- stacking: hard mean X-ray spectrum
- X-ray detections: high fraction of X-ray sources in post-starbursts (98% significance)

# Stellar population of AGN hosts at z~1: evidence for starbursts?

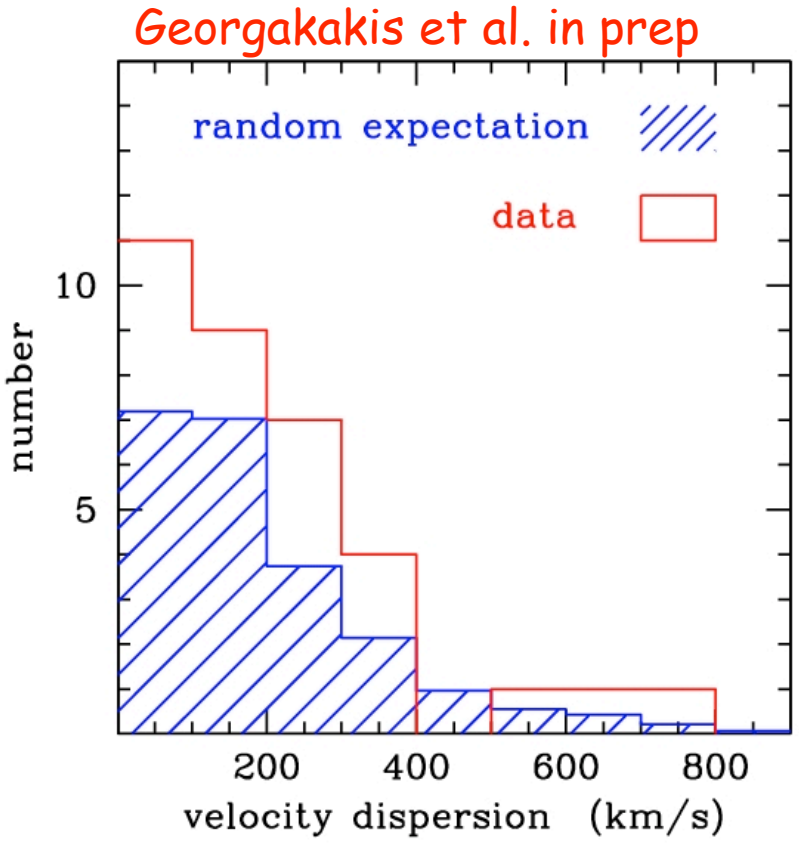
- CDF-South:
  - X-ray: AGN
  - Ultra-deep radio (1.4GHz): dominated by starbursts
- mid-IR: Radio emission of some AGN associated with star-formation



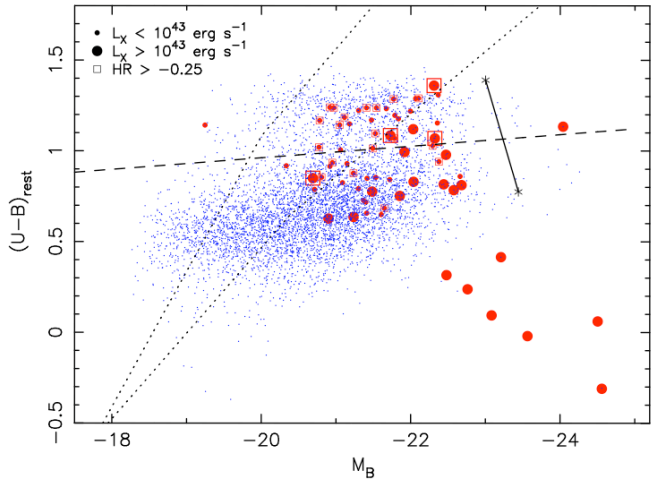
# Environment of AGN at z~1: field or groups?

AEGIS group catalogue (Gerke et al. 2005)

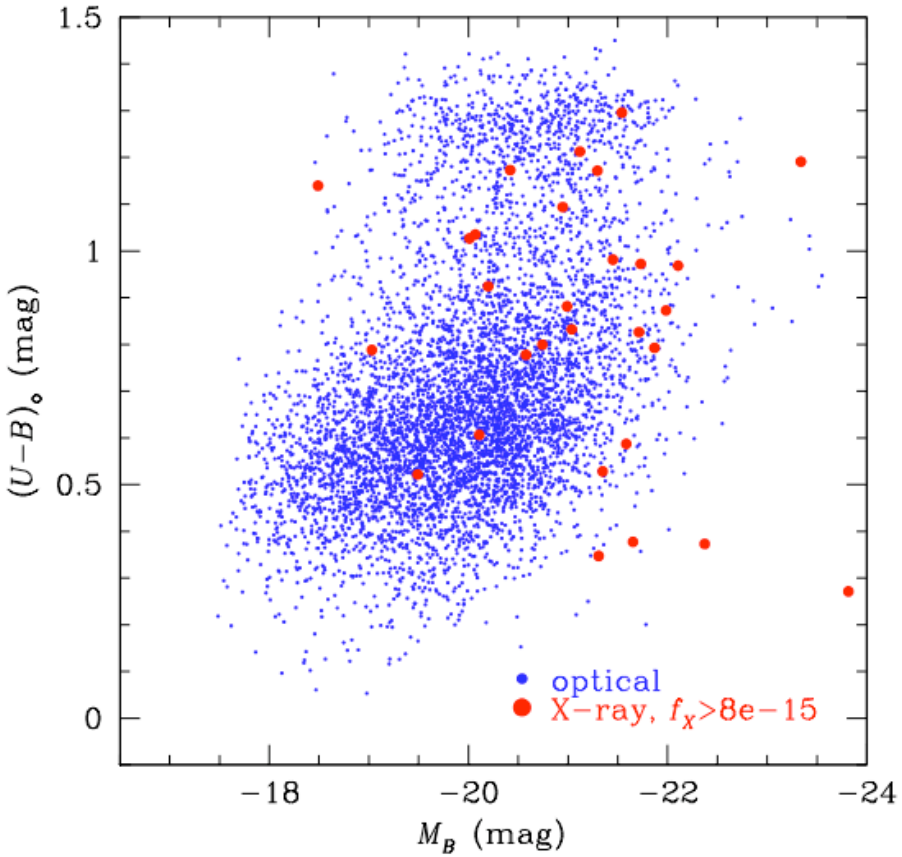
40% of AGN in groups



# DEEP VS WIDE




Nandra et al. sample (200ks)

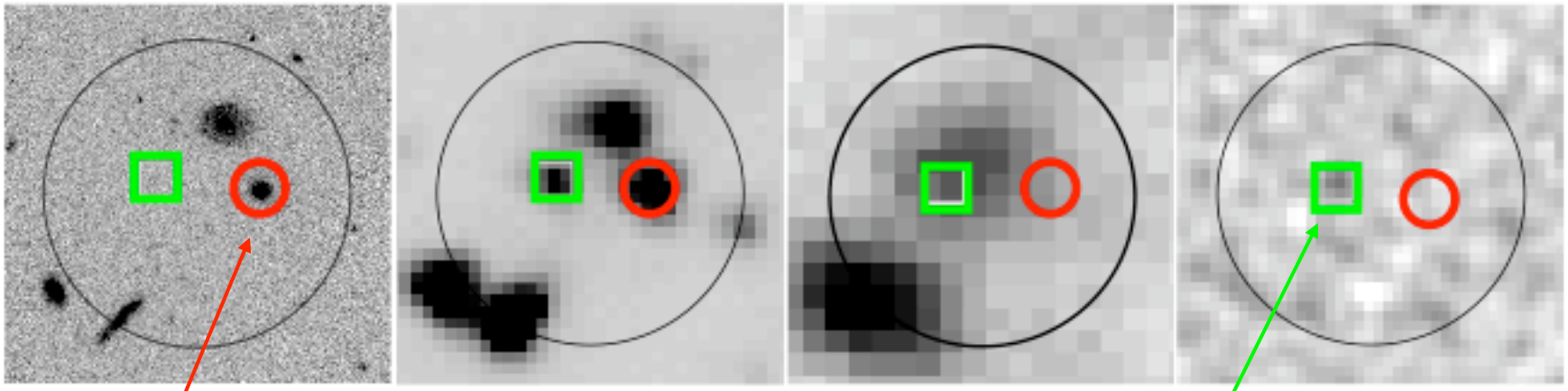



Bright sources only (~Bootes limit)

# OPTICAL IDENTIFICATION

ID of SCUBA source GN11 (w/Alex Pope + Douglas Scott UBC)

HST/ACS IRAC 3.6mm MIPS 24mm radio



**Alexander et al X-ray c/part**

**Pope et al. c/part**

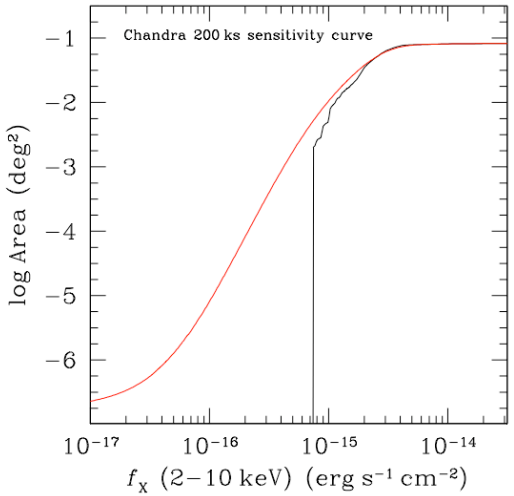
⇒ **SCUBA AGN fraction may be lower than Alexander et al. (2005)**

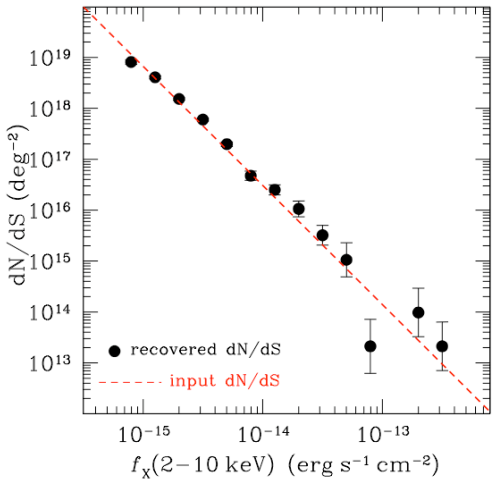
- Chance projections in AEIGS to I=25:
  - 7% IDs at 1.5"; **20% at 3"**; 30% at 5"
  - REAL IDs are optically fainter ⇒ high z?

⇒ **MAJOR IMPACT ON NUMBER OF HIGH Z AGN/REIONIZATON**

# X-RAY INCOMPLETENESS

- X-ray images are
  - Highly inhomogeneous
  - In poisson regime
- Source detection “black box” (e.g. wavdetect)
- Detection inconsistent with sensitivity
- Eddington bias, poisson noise, incompleteness
- Embodied in sensitivity curve




Georgakakis et al., in prep

# DO X-RAY SURVEYS FIND ALL AGN?

- Heckman et al. (2005) say OIII better at selecting local AGN than X-ray
- Steidel et al. (2002) found 70% of X-ray AGN at z=3 LBGs from spectroscopy
- Also one AGN X-ray undetected in 1 Ms
- Sarajedini et al. (2006): 70% of optically variable nuclei X-ray undetected (200ks Chandra)
- AEGIS (Renbin Yan, Berkeley):
  - 60% of X-ray sources have AGN line ratios
  - 10% have no OIII
  - **Only 30% of line-ratio selected (candidate) AGN are X-ray sources!**

Not to mention Spitzer selection… need multi-λ approach

But remember flux limits…

# OTHER ISSUES

- Separating AGN and starbursts
- Is it reasonable to assume Compton thick evolve like unobscured
- Is alpha_ox dependent on UV luminosity really?
- How does variability affect SEDs. Dispersion?
- Effects of variability effects on photoz?

# CLUSTERING vs. HOST LUMINOSITY